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EDITORIAL NOTES.

IN his Presidential Address to the British Association at Cardiff, Professor Herdman gave an admirable summary of the modern developments of his special subject, Oceanography. This new science comprises portions overlapping from many other fields of research, and Professor Herdman naturally dealt at length with the biological side of it, but even the biology of the deep sea affords evidence as to geological problems, while the geological value of physical oceanography needs no extended demonstration.

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THE President of Section C, Dr. F. A. Bather, devoted his address to a comprehensive review of the present position of biological science from the point of view of evolution. This subject naturally appeals very strongly to a palæontologist, but Dr. Bather did not by any means confine himself to extinct forms. He also quoted modern instances where necessary. We hope to give in a later number a summary of some of the main points brought forward in this admirable address, which should do much to stimulate interest in the newer and more philosophical ideas which are now exerting so much influence in the development of palæobiology.

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IN our correspondence columns we print a letter from Professor Marr, inquiring whether any of our readers can assist him in discovering the whereabouts of certain implements found by the late Mr. S. B. J. Skertchly from deposits around Brandon and Mildenhall, in Suffolk, and supposed to be of Mid-Glacial age. It is unnecessary to enlarge on the importance of these implements, if still in existence, and we hope some information may be forthcoming.

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THE loss last month of Sir Norman Lockyer, K.C.B., F.R.S., deprives us of a distinguished astronomer and physicist and the founder, in 1869, of the well-known weekly scientific journal *Nature*, whose "jubilee" was held last year. Born at Rugby in 1836, he was appointed a clerk in the War Office in 1857, Director of the Solar Physics Observatory, South Kensington, 1885–1913, President of the British Association 1903–4, Director of *eight* English Eclipse Expeditions (between 1870 and 1905),

and author of numerous books and papers on astronomy and physics.

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Death has deprived us of Professor John Perry, D.Sc., F.R.S., late of the Royal College of Science, South Kensington (1850–1920), who, with Professors Ayrton and John Milne, was among the first on the staff of the Imperial College of Science, Tokio, Japan; Professor of Mathematics and Engineering, City and Guilds of London Technical College, Finsbury; President of the Physical Society; for many years General Treasurer of the British Association; author of numerous scientific papers, a most popular lecturer, and beloved by a wide circle of men of science.

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The Mining Industry Act, 1920, which is the latest version of the measure for the establishment of a Ministry of Mines, has undergone a good deal of modification in its passage through Parliament. Some of these changes have to a certain extent met the objections raised in a former issue of the Magazine. Thus we find that it is now provided that two advisory committees must be appointed by the Board of Trade, one to deal with coal, the other with metalliferous mining. The constitution of the coal committee is set out in detail; out of a total twenty-four members only one is to be a mining engineer, and there is provision for the inclusion of a number of faddists of various kinds. There is a delightful vagueness about the clause "three [members] shall be persons with expert knowledge of medical or *other* science": the italics are ours. As to the constitution of the committee on metalliferous mining nothing is said. Section 21, subsection 2, provides that no information with respect to any particular undertaking shall be included in any published report. This is a retrograde step, since in Section 10 of the Metalliferous Mines Act of 1872 power is given to the Secretary of State to collect statistics, and there is no limitation of his power to publish them. If this new provision is enforced no details can be given as to the output of particular mines, as has hitherto been done, for example, in the case of hematite mines.

BONUM CERTAMEN CERTAVI
IN MEMORY OF
JAMES NICOL
F.R.S.E. F.G.S.
BORN AT MANSE OF TRAQUAIR PEEBLESHIRE A.D. 1810 DIED IN LONDON A.D. 1879 PROFESSOR OF GEOLOGY & MINERALOGY CORK 1849-54 OF CIVIL AND NATURAL HISTORY ABERDEEN 1853-79 HIS VIEW ON THE SUCCESSION OF THE ROCK GROUPS OF THE NORTH WEST HIGHLANDS DISPUTED WHILE HE LIVED WERE CONFIRMED BY THE OFFICERS OF THE GEOLOGICAL SURVEY IN 1884
LEAVING TIME & THE UNCHANGING MOUNTAINS TO CONFIRM OR REFUTE

MEMORIAL TABLET ERECTED TO
PROFESSOR JAMES NICOL, F.R.S.E., F.G.S.,
IN THE UNIVERSITY OF ABERDEEN, 1ST JULY, 1920.

Designed and executed by Alice B. Woodward.

The Nicol Memorial.

(PLATE VI.)

A MURAL tablet, to the memory of Professor James Nicol, F.R.S.E., F.G.S., formerly of Aberdeen University, was unveiled by Dr. John Horne, F.R.S., in Marischal College, and entrusted to the Principal, Sir George Adam Smith, on July 1.

The memorial was presented by a number of well-known geologists who were his friends and admirers and desired to commemorate in some permanent form their high estimation for this distinguished teacher in the University during a quarter of a century, and also to record his original contributions to Scottish geology, the value and importance of some of which were not fully appreciated and confirmed until after his death.

The memorial (see Plate VI) is placed side by side with that of Professor Nicol's successor, Professor Henry Alleyne Nicholson,[1] in the same chair, and was designed and executed by the same artist, Alice B. Woodward, daughter of Dr. Henry Woodward, F.R.S., in the form of a bronze tablet in repoussé-work mounted on oak (measuring 4 feet by 3 feet), bearing the modelled profile medallion of Nicol with name and titles. Beneath the portrait in close raised letters, in twelve lines, is given an epitome of his career with dates, as follows :—

BORN AT MANSE OF TRAQUAIR
PEEBLESHIRE AUG. 1810, DIED IN
LONDON AP. 1879. PROFESSOR OF
GEOLOGY & MINERALOGY CORK
1849–53. OF CIVIL AND NATURAL
HISTORY ABERDEEN 1853–78.
HIS VIEWS ON THE SUCCESSION OF THE
ROCK GROUPS OF THE NORTH-WEST
HIGHLANDS, DISPUTED WHILE
HE LIVED, WERE CONFIRMED
BY THE OFFICERS OF THE
GEOLOGICAL SURVEY IN 1884.

Below is quoted a phrase used by the Professor himself—

"LEAVING TIME AND THE UNCHANGING
MOUNTAINS TO CONFIRM OR REFUTE."

Above, the tablet bears the words—

BONUM CERTAMEN CERTAVI,

and in low relief is given a sketch of Na Tuadhan, a mountain north of Ben More Assynt, showing typical foldings.

On the border of the tablet are figures of Graptolites, *Monograptus romerinus* Nich. and drawings of *Maclurea Peachii* Salter and two of the Trilobites, *Olenellus Lapworthi* and *Olenelloides armatus*, discovered in 1892–4 by the Geological Survey.[2]

[1] See Memorial Tablet to Professor H. A. Nicholson, F.R.S., GEOL. MAG., 1903, pp. 451–2, Plate XXI.

[2] See Drs. B. N. Peach & J. Horne, "*Olenellus* Zone in the North-West Highlands of Scotland": Quart. Journ. Geol. Soc., vol. xlviii, 1892, pp. 227–41, with sections and plate v (Trilobites). Id., addition to fauna of same, vol. l, 1894, pp. 661–75, pls. xxix–xxxii (Trilobites).

On behalf of the subscribers, Dr. John Horne, F.R.S., addressed the Principal, Sir George Adam Smith, as follows :—

Sir George,—We have met here to-day to do honour to Professor James Nicol, who for more than a quarter of a century was one of the teachers of Natural Science in this University, and whose contributions to Scottish geology were of the highest value. He was a remarkable example of the best traditions of Scottish University life, for, in addition to the prime duty of instructing students, he regarded the prosecution and encouragement of original research as an essential feature of the work to be done by a scientific department.

This memorial is intended to be a permanent record of the value of his contributions to the solution of the problem of the geological structure of the North-West Highlands. In the first half of last century that region was visited by Macculloch, Murchison and Sedgwick, Hay Cunningham and Hugh Miller, who had described the picturesque mountains of red sandstone, overlain by quartzites and limestones, in the west of the counties of Sutherland and Ross. They recorded that these unaltered strata rest upon a platform of crystalline gneiss and schist, and are succeeded eastwards by metamorphic rocks that stretch across the Great Glen to the eastern border of the Highlands.

The discovery of fossils in the Durness limestones in the north of Sutherland (in 1854) by Mr. Charles Peach raised questions of vital geological importance connected with the structure of that region and the age of the crystalline schists associated with these limestones.

Nicol's field work in the North-West Highlands began in 1855, not long after his appointment to the Professorship in this University. His first examination of the ground was carried out in association with his friend Sir Roderick Murchison, but all his subsequent work was done by himself, for they differed as to the interpretation of the structure.

Adopting the determination of the fossils made by J. W. Salter, the palæontologist of the Geological Survey, Murchison referred the quartzites and limestones to the Silurian system. He further contended that as the fossiliferous limestones passed normally below the crystalline schists to the east, therefore these schists themselves must belong to the same system. Hence, with one bold sweep of the brush, Murchison coloured as Silurian the extensive region stretching from near Durness to Stonehaven, and from Fraserburgh to the Mull of Kintyre. This interpretation involved a radical change in the geological map of Scotland.

Nicol's interpretation was fundamentally different. With untiring energy he continued his work in the field for several years and issued a series of papers containing the results of his researches. From time to time he modified his views, abandoning positions which he found to be untenable, and stating the evidence for changing

his opinions. In the development of his researches he showed sterling honesty of purpose.

His work in the field may be summed up in two propositions. First, he showed that the red sandstone formation, which he named the "Torridon Sandstone", was separated from the overlying quartzites and fossiliferous limestones by a great unconformity, implying a gap in the geological record. This important structural feature was traced by Nicol for a distance of one hundred miles from the north of Sutherland to Loch Kishorn. Second, he contended that no conformable upward succession from the fossiliferous limestone to the overlying schists is to be found. To quote his own words: "The line of junction, where this conformable succession is said to occur, is clearly a line of fracture, everywhere indicated by proofs of fracture, contortion of the strata, and powerful igneous action."

Such widely different interpretations gave rise to keen controversy. The progress of geology, like that of other sciences, is bound up with controversy. The brethren of the hammer fight keenly; indeed, the *odium geologicum* rivals at times the *odium theologicum*.

Murchison's order of succession, which was supported by Sir Andrew Ramsay, Professor Harkness, and Sir Archibald Geikie, met with general acceptance because it furnished such a simple solution of the problem.

In 1878 the controversy was reopened and Murchison's position was shown to be untenable by several investigators, of whom the most prominent was the late Professor Lapworth,[1] followed by Dr. Callaway,[2] Professor Bonney,[3] Dr. Hicks, and others.

In 1883 the Geological Survey began the detailed mapping of that region. The results of their work completely confirmed Nicol's main conclusions.[4] We now know that the structure of that mountain chain is intensely complicated, far more complicated than Nicol imagined. Under extreme lateral pressure the rocks have behaved like brittle rigid bodies; they have snapped

[1] Professor Charles Lapworth, "The Secret of the Highlands": GEOL. MAG., 1883, pp. 120–8, 193–9, 337–44. "On the Stratigraphy and Metamorphism of the Rocks of the Durness–Eireboll District": read at the Ordinary Meeting of the Geologists' Association, July 4, 1884, by Professor C. Lapworth; printed as read, with a few words added in brackets for clearness of description, by J. J. H. Teall, GEOL. MAG., 1885, pp. 103–6. Professor C. Lapworth, "The Close of the Highland Controversy": GEOL. MAG., 1885, pp. 97–103.

[2] Dr. Callaway, Quart. Journ. Geol. Soc., May, 1881; GEOL. MAG., 1883, p. 139. Id., "Torridon Sandstone and Ordovician Rocks of the Northern Highlands": Q.J.G.S., vol. xxxviii, 1882, pp. 114–17. Id., "Age of the Gneissic Rocks of the Northern Highlands": Q.J.G.S., vol. xxxix, 1883, pp. 355–414.

[3] Professor T. G. Bonney, "Lithological Character of Scottish Rocks" (Dr. Hicks' Collection): Quart. Journ. Geol. Soc., vol. xxxix, 1883, pp. 159–66; (and Dr. Callaway's Collection), vol. xxxix, pp. 414–20.

[4] Drs. B. N. Peach & J. Horne: "Preliminary Report on the Geology of the Durness–Eireboll District": *Nature*, November, 1884, vol. xxxi, p. 19.

and have been driven westwards in successive slices, so that crystalline gneiss and schist are made to rest upon fossiliferous strata of Cambrian age. But Nicol's main contention was proved beyond doubt that there is no conformable sequence in the North-West Highlands from the quartzites and limestones into the overlying schists. In grappling with the structure of this old mountain chain there can be no question that Nicol displayed the qualities of a great stratigraphist.[1]

Since the publication of the results of the Geological Survey work, that region has been visited by many of the leading geologists in Europe and North America, who have been profoundly impressed with the light which it throws on the building of an old mountain chain by folding and terrestrial displacements.

It is a source of genuine pleasure to me to present this memorial on behalf of the subscribers to you, Mr. Principal, for the preliminary report on the geology of the Durness–Eireboll district, published in *Nature* in 1884 by my old friend and colleague Dr. Peach and myself, led to the final abandonment of the Murchisonian hypothesis.

In the custody of yourself and your successors it will recall the labours of one whose name is inseparably linked with the solution of one of the great problems in British geology.

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The following is a brief abstract of Professor Nicol's life, taken from his obituary by Professor Lapworth (Quart. Journ. Geol. Soc., 1880, Proc., pp. 33-6), and may serve to show the leading features in his career and explain the silence which marked the latter years of his strenuous life.

More than a century ago James Nicol was born at Manse of Traquair, Peeblesshire, in 1810. His father, the Rev. James Nicol, was well known for his poetical writings. After his father's death in 1819, young Nicol lived with his family in Inverleithen, where his early education was completed by the Rev. Mr. Pate. His rambles amid the bold and picturesque scenery of the district led him early to study its geology. The absence of fossils and of clear sections in these old rocks directed Nicol's attention more especially to their mineralogical aspect, still further encouraged by his subsequent attendance on the classes of Professor Jameson. He entered the University of Edinburgh in 1825, where, after passing the Arts and Divinity courses, he went to Germany and studied at the Universities of Berlin and Bonn. On the conclusion of his University training he returned to Scotland, and devoted himself to the geology of the valley of the Tweed, and in 1841 he was awarded prizes by the Highland Society for his essay on the Geology of

[1] Quart. Journ. Geol. Soc., vol. xii, 1857, pp. 17-39, with sections; and C. Lapworth, "Theory of Professor Nicol": GEOL. MAG., 1888, p. 123.

Peeblesshire,[1] and subsequently for one on the Geology of Roxburghshire.

During the ensuing years he made extensive geological journeys throughout Scotland, more especially in its southern portions. The results of these investigations were published in the form of *A Guide to the Geology of Scotland*, illustrated by plates and a small geological map of Scotland.

In 1847 James Nicol was appointed Assistant Secretary to the Geological Society of London, and for two years he edited the "Quarterly Journal" of the Society. Here he gained the friendship of many of that illustrious group of British geologists which then assembled at its meetings. In this congenial atmosphere Nicol's mineralogical studies were prosecuted with increased ardour; and in 1849 he published his well-known textbook of mineralogy.

First among his geological friends stood Sir R. Murchison, and through his influence, and that of Sir H. De la Beche and Sir Charles Lyell, Nicol was appointed in 1849 to the post of Professor of Geology and Mineralogy in Queen's College, Cork. But in 1853 he relinquished the post for the more lucrative position of Professor of Natural History in the University of Aberdeen, which he retained till his death in 1879.

In spite of his predilection for mineralogy, it is beyond question that Nicol will be remembered less for his mineralogical works than for his numerous and valuable memoirs upon the stratigraphy of Scotland. His papers upon the Geology of the Southern Uplands of Scotland are of especial interest and value. In 1848 he published a memoir "On the Rocks of the Valley of the Tweed" (Quart. Journ. Geol. Soc., iv, p. 195), demonstrating their fossiliferous character, and a general view of the entire succession among the transition rocks of South Scotland, and applying to them for the first time the title of "Silurian". In 1849 he communicated a memoir "On the Silurian Rocks of the South-East of Scotland" (Quart. Journ. Geol. Soc., vol. vi, p. 53), in which for the first time Graptolites were figured from these ancient deposits. In 1850 he accompanied his friend Sir R. Murchison in a tour through the Southern Uplands, and aided him in his detailed investigation of the geology of the fossiliferous Girvan area. In 1852 he communicated a complete résumé of the results of his extended researches into the geological structure of the Southern Uplands, illustrating it by the first complete transverse section through the Silurian rocks from the Pentlands to the Cheviots. A reduced copy of this section illustrated all the subsequent editions of Murchison's *Siluria*, and stood substantially unmodified in the official publications on South Scottish geology, until the true order of succession, based on the graptolites, was established by the late Professor Lapworth.

During his residence in the University of Aberdeen Nicol

[1] In the first of these publications the presence of fossils in the Lower Palæozoic rocks of the Inverleithen district was first made known.

transferred the sphere of his geological investigations to the metamorphic rocks of the Highlands, which in 1844 he had suggested were probably of the same geological age as those of the Southern Uplands. In 1855 he published his paper "On the Sections of Metamorphic and Devonian Rocks of the Eastern Extremity of the Grampians" (Quart. Journ. Geol. Soc., vol. xi, p 544).

The same year he visited the well-known Torridon and Durness area in the North-West Highlands in company with Sir R. Murchison, in order to verify Mr. Peach's discovery of fossils in the metamorphic limestone of that region. On his return he communicated an independent memoir to the Geological Society (Quart. Journ. Geol. Soc., vol. xiii, p. 17), in which he claims to have published for the first time their order of succession, viz. : (*a*) Lower Gneiss ; (*b*) Conglomerate and Red Sandstone ; (*c*) Quartzite ; (*d*) Limestone, overlain by (*e*) an Upper Gneiss. Arguing mainly from the petrographical character of these rocks, he threw out the suggestion that the Torridon Sandstone might be of Devonian age, and that the overlying limestone and gneiss might be of the age of the Lower Carboniferous. After Mr. Salter's demonstration that the fossils of the Durness Limestone were not Carboniferous, but belonging to the deepest zone of Murchison's Silurian, Nicol again visited the North-West Highlands. In a memoir giving the chief results of this expedition (Quart. Journ. Geol. Soc., xvii, p. 85) he retraced his former admission of an Upper Gneiss, superior to the Durness Limestone ; and claimed to have proved that the line of demarcation between the Durness series and the eastern gneiss of Central Sutherlandshire is actually a line of fault, the Torridon and Durness strata always overlying or abutting against, but never dipping under, the eastern gneiss. These opinions led to a keen controversy between himself and his old friend Sir R. Murchison ; but after the publication of two additional memoirs on the subject in 1862 and 1863, in which he defended his view that the central gneiss of the Highlands is of the same general geological age as the Lewisian gneiss of the Outer Hebrides, and that the only metamorphic strata that can safely be called "Silurian" are the less altered rocks upon the outer borders of the Highlands, he ceased to contribute papers to the Society upon the subject. A little work, *On the Geology and Scenery of the North of Scotland*, contains his last published words upon the subject.

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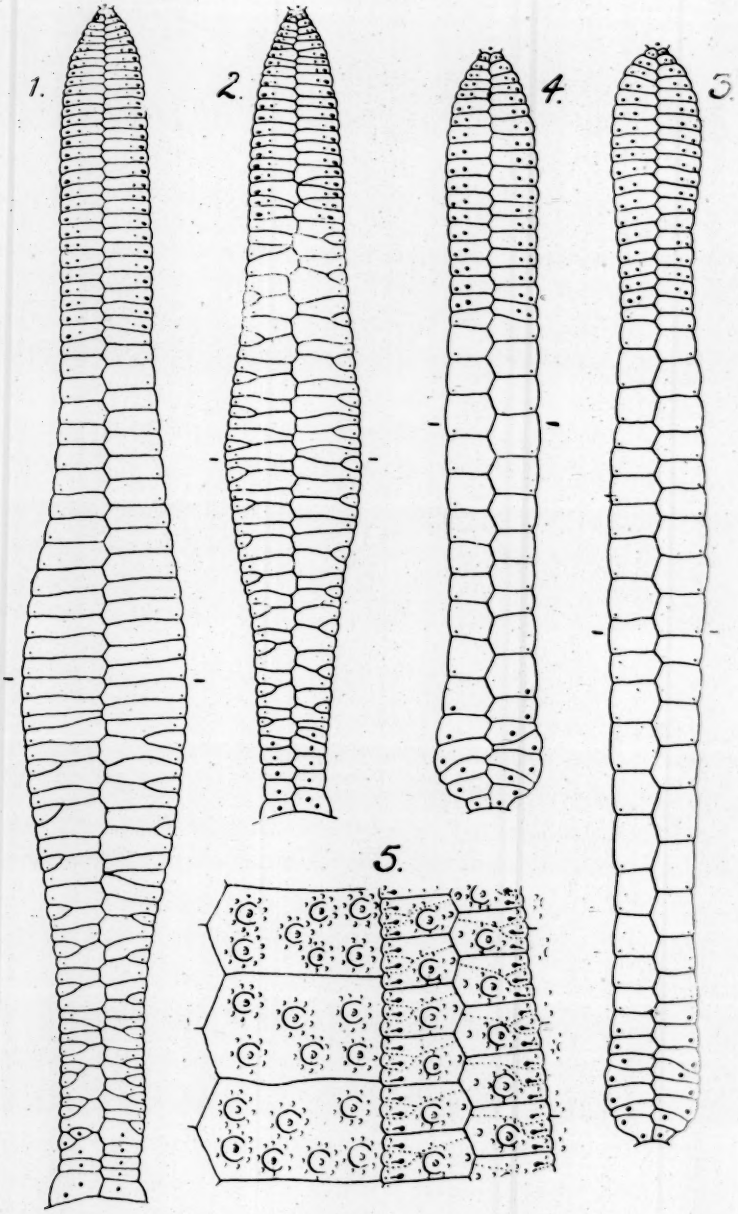
"The Close of the Highland Controversy," written by Professor Lapworth (see GEOL. MAG., 1885, pp. 97–106), and the admirable but brief address by Dr. John Horne (*ante*, pp. 388–90), furnish a suitable note to Professor Nicol's life and researches, most of the friends and contemporary actors in which have now, like himself, "ceased from their labours." But the value of their conclusions have left a permanent impress for good on the modern school of geological thought and science which can never be forgotten.—H.W.



H. L. H. del.

AMBULACRA OF *APATOPYGUS*, *OLIGOPODIA*, AND YOUNG *ECHINOLAMPAS*.

To face p. 393.]

ORIGINAL ARTICLES.

Morphological Studies on the Echinoidea Holectypoida and their Allies.

X. ON *APATOPYGUS* GEN. NOV. AND THE AFFINITIES OF SOME RECENT NUCLEOLITOIDA AND CASSIDULOIDA.

By Herbert L. Hawkins, D.Sc., F.G.S., Professor of Geology, University College, Reading.

(PLATE VII.)

1. Introduction.

While collating the plates in a recently acquired copy of the *Revision of the Echini* (A. Agassiz, 1872–4), I noticed with surprise a representation of complex ambulacral structure in "*Echinobrissus*" *recens* (pl. xiv *a*, figs. 3–4). A style of plate-grouping essentially similar to that in *Echinoneus* (tab. cit., figs. 7–8) is portrayed as affecting all the extra-petaloid parts of the five areas, and encroaching slightly on the distal parts of the petals. No reference to this unusual condition occurs in the text. As the proofs of my recent paper on ambulacral structures (Phil. Trans., B, vol. 209) were in my hands at the time, I was immediately impressed by the remarkable resemblance between "*E.*" *recens* and the Cretaceous *Trematopygus*—a correspondence by no means restricted to ambulacral plating, but involving all coronal features save the orientation of the peristome.

Within an hour of the discovery a letter was dispatched to Dr. H. L. Clark, of the Museum of Comparative Zoology, Cambridge, Mass., asking if he could confirm the presence of the structure indicated, and begging for any fragments of "*E.*" *recens* that could be spared. By return mail he sent me entire tests of three rare Echinoids, "*E.*" *recens* (to him an *Oligopodia*), *Oligopodia epigonus*, and *Rhynchopygus caribœarum*. He encouraged, nay commanded, me to work my will on the beautiful specimen of the first-named species, even if pulverization were the result, and placed but few restrictions on my treatment of the others. Some idea of the disinterested generosity shown can be conveyed on two counts. In the first place the specimens are recent forms on which Dr. Clark has been working lately, thereby "staking a claim" in them whose justice all would admit. But he handed them over to the tender mercies of a palæontologist who had not the temerity to ask for them! Secondly, Agassiz Museum possesses only four specimens of "*E.*" *recens* (one of which I was instructed to destroy), two of *O. epigonus* (the better of which, figured in the *Revision*, pl. xix *b*, figs. 4–6, is in my hands), and two of *R. caribœarum*.

The liberty and fraternity of science could scarcely have had more convincing exposition. In publicly expressing my gratitude to Dr. Clark and the Museum with which he is connected, I feel

constrained to hope that the spirit herein manifested may inspire an ever-growing *ecclesia* of individuals and institutions. A Museum whose aim is to acquire and store away a miserly hoard of rarities is in danger of becoming a mausoleum rather than a radiant centre of vitality in research; the individual who fails to welcome discoveries, even when they might have been his own, is no apt disciple, still less a true apostle, of the creed of science.

Of the three specimens sent for study "*O.*" *recens* is now in ruins (though even yet beautiful); *O. epigonus* has acquired a coloration unlike that secreted by any known Echinoid, and has unfortunately lost its apical system; while *R. caribœarum* has suffered removal of many of its radioles. It is my earnest hope that the following notes may atone in some measure for the damage done, and convey in the most acceptable form my thanks for the prompt and almost reckless generosity that enabled me to investigate material at once so precious and so interesting.

2. Apatopygus recens (Milne Edwards).

This species was introduced by Milne Edwards in 1836 (Cuvier, Regn. Anim. Zooph., pl. xiv, fig. 3), under the name *Nucleolites recens*. At that date *Nucleolites* was a broad generic term covering all Irregular Echinoids which have the periproct on the adapical surface; but in this particular case the close superficial similarity between *N. recens* and such fossil forms as *N. scutatus* made application of the name unusually appropriate. D'Orbigny in 1854 (Rev. Mag. Zool.) automatically replaced *Nucleolites* by the pre-Linnean *Echinobrissus*, but no reasoned attempt at better generic precision was made until 1889, when Duncan (Journ. Linn. Soc., vol. xxii) proposed *Oligopodia* as a subgenus, including the two recent species of "Nucleolitidæ" then known, *recens* and *epigonus*. In 1904 Hamann (Bronn's *Thierreichs*) raised *Oligopodia* to generic rank, and restricted it to *O. epigonus* (Martens), which thereby became the genotype. "*Echinobrissus*" *recens* was left in *Nucleolites* by Hamann, but Clark (1917, *Hawaiian and other Pacific Echini*, p. 107), believing *recens* and *epigonus* to be congeneric, and "quite different from typical *Nucleolites* of Lamarck", placed both under *Oligopodia*.

While concurring in Clark's opinion that both are incapable of bearing the name *Nucleolites*, I am fully convinced that they are so far from being congeneric that family, and indeed ordinal, distinctions separate them. The reasons for this belief are subjoined, but the systematic sequel can be indicated here. *Nucleolites epigonus* Martens is the lecto-genotype (Hamann, 1904) of *Oligopodia* Duncan, 1889. *Nucleolites recens* M. Edwards is certainly not a *Nucleolites* in the accepted sense of the term, and is even less akin to *O. epigonus*. A new generic name is thus necessary for *N. recens*, unless that species can be shown to belong to some other genus already diagnosed. The latter condition does not obtain, so far as I can determine,

so that I hereby establish the new genus *Apatopygus*,[1] whose genotype and only known species is *Nucleolites recens* Milne Edwards, 1836. A detailed diagnosis of the genus concludes this section of the paper.

The description of *Apatopygus recens* (sub *Echinobrissus*) given by A. Agassiz (*Revision*, pp. 556–7) is sufficiently full and in agreement with the specimen before me to serve with but little comment. The description of the peristome and its surroundings is accurate, but Agassiz' use of the term "phyllode" might prove misleading. There is no more trace of phyllodal qualities, whether of plating or pore-disposition, in the orad parts of the ambulacra than occurs in an ordinary Spatangid. The proximal pores are appreciably larger than the others, and tend to perforate their ambulacrals in the median line rather than near the adradial sutures; but the pores show less tendency towards triserial arrangement near the peristome than on the rest of the adoral surface, while the plating is almost perfectly simple and "Cidaroid" in the region where the pores increase in size. With regard to the interambulacral parts of the peristome-margin, there can be no doubt that Agassiz' remark that "no buccal bourrelet had been developed" is an under-statement. As far as such a condition is conceivable it may be said that "bourrelets" are positively absent—the proximal interambulacrals are exceptionally thin in their invaginated parts, resembling those of *Echinonëus* more than those of any other recent Echinoid with which I am acquainted, and exceeding them in delicacy. The quality expressed in the generic description (loc. cit., p. 556) "Floscelle rudimentary; no well-marked bourrelets" would, to my mind, be better abbreviated to the bare statement "no floscelle".

The nature of the ambulacral plating, which is roughly indicated in Agassiz' figures, but not mentioned in the text, seems to me to provide the most unusual and distinctive feature in *A. recens*. Analyses of one of the longest areas (I) and the shortest area (III) are here given (Plate VII, Figs. 1 and 2). As far as indications go, area II (which is almost midway between the extremes in point of length) resembles the latter more closely than the former. In all ambulacra, practically the entire extent of the adoral parts (excluding the peristomial portions above mentioned) display typically "Pyrinid" plating (see Hawkins, Phil. Trans., 1920), the demiplates often undergoing great reduction. In area I this condition ceases just below the ambitus, and the adapical part of the area is built of simple primaries, some of which (below the petals) may be almost half as high as broad. The petal consists of thirty plates in each column, perforated by dissimilar pore-pairs. In area III, Pyrinid structure persists up to, and even into, the petaloid region with characters indistinguishable from those present adorally.

[1] ἀπατάω, I deceive, and *-pygus*, normal suffix for genera of this group.

There are twenty-one or twenty-two plates in each column of the petal. Three or four of the distal plates of this region show incipient Pyrinid grouping, while a trifling imperfection of alternation affects both columns quite near the apex. (This last may well be but an individual irregularity.) The indications of structure given in Agassiz' figures are therefore confirmed (broadly speaking); but he represents Pyrinid plating as continuous to the petals in all five areas, while it certainly does not extend above the ambitus in areas I and V in the specimen before me, and seems not to reach the petals in II and IV.

The two features described above contain sufficient evidence for generic separation of *A. recens* from *O. epigonus* (Pl. VII, Figs. 3 and 4), although many others could be cited. In the latter species there is a perfectly definite floscelle, with expanded (though structurally simple) phyllodes and well-marked, typical interambulacral bourrelets. There is no trace of ambulacral complexity above the phyllodes; all ambulacrals between these and the petals are about as high as broad, and in consequence the number of podial pores is very small. All five petals are of the same length, and contain the same number of plates; while the petaloid pores are large and perfectly similar. The name *Oligopodia* is eminently appropriate for *epigonus*, but it would be grotesque to apply it to *recens*, where the number of ambulacral plates (and podia) is vastly in excess of expectation for so small a form. *O. epigonus* is a typical "Cassiduloid", and resembles *Rhynchopygus* and *Echinolampas* in ambulacral characters, as in many others. As Agassiz remarked, it is closely similar to the Cretaceous genus *Caratomus*. The affinities of *Apatopygus* will be discussed in the next section, but a diagnosis of the genus is now possible.

Apatopygus gen. nov., Hawkins, 1920.

Genotype and sole species, *Nucleolites recens*, M. Edwards, 1836.

Nucleolitoida, Nucleolitidæ. *Test* depressed, subquadrate, with greatest width behind the apex. *Ambitus* rounded, adapical surface rising to a low, almost median summit; adoral surface slightly tumid, strongly invaginated at the peristome. *Apical system* eccentric anteriorly, built of five small oculars and four genitals, of which the madreporic plate occupies the centre of the system, and just separates the posterior oculars. *Peristome* deeply invaginate, eccentric anteriorly, transversely elliptical, with thin marginal plates. *Periproct* longitudinally elliptical, situated in a deep sulcus to which it forms the apicad wall, about midway between the apex and the posterior margin of the test. Anus surrounded by a many-plated membrane, the largest plates being posterior and external. *Interambulacra* wide, built of fairly low plates bent near the median line of each column. Proximal orad interambulacrals large, single, and very thin. Tubercles large for a Nucleolitoid, scrobiculate, imperforate; arranged in quincunx on apicad and orad plates. *Ambulacra*

petaloid, narrow, widest at the ambitus. Posterior petals longer than anterior; that of area III the shortest. Petaloid pores dissimilar, outer pores elliptical and larger than the inner, round, pores. Extra-petaloid pores single and small, three or four in the peristomial invagination being slightly larger than the rest, but not attaining the size of the outer petaloid pores. Pore-series irregularly uniserial (with tendencies to triserial arrangement below the ambitus), convergent adorally. Proximal orad plates primaries (biporous ambulacrals present) within invaginated parts. Thence to ambitus typical "Pyrinid" plating, most intense (in part Discoidiid) in areas I and V. Similar plating continued above the ambitus into distal part of petal in area III, ? almost to petals in II and IV, but not reaching above ambitus in I and V. In areas last-named supra-ambital, non-petaloid plates are relatively high. Petals (except in III) uniformly Cidaroid in plating.

Recent: New Zealand and ? Madagascar.

3. The Affinities of *Apatopygus*.

The entire facies of the test of *Apatopygus* agrees very closely with that of *Nucleolites*, and is superficially almost identical with that of *Trematopygus*. The large size of the peristome, and the marked disparity in length of the petals are obvious features that distinguish it from the former, while the directly transverse elongation of the peristome runs counter to the diagnostic character of the latter. The ambulacral structure, with which this paper is mainly concerned, clearly separates *Apatopygus* from *Nucleolites*, and approximates it to *Trematopygus*. It is needless to argue further the close relationship connecting all three genera. To my mind the original contention that "*Nucleolites*" *recens* is a latter-day survivor of the essentially Mesozoic Nucleolitoida is perfectly justified.

In respect of ambulacral structure, it is possible to recognize four types in the Nucleolitidæ (*sens. str.*), each of which can be ascribed to a more or less defined place in stratigraphical history. The Lower Oolitic type (e.g. "*Nucleolites*" *quadratus*, see Phil. Trans., vol. 209, pl. lxviii, fig. 2) had well-marked, congested petals, and strictly limited phyllodes containing many occluded plates. The Upper Oolitic type (e.g. *Nucleolites scutatus*, loc. cit., pl. lxviii, fig. 3) had less-restricted, little-congested petals, and ill-defined hypophyllodes in which occluded plates are rare, but demi-plates may occur. The Cretaceous type (*Trematopygus*, loc. cit., pl. lxviii, fig. 4) had long, many-plated, but feebly expanded petals, and a strangely diffuse, vestigial kind of hypophyllode, in which Pyrinid plating covers much of the adoral extent of the ambulacra, being least extensive in areas I and V. The fourth type is *Apatopygus*, with long but uncongested petals, and an exaggerated state of diffusion in the "hypophyllode", which shows features normal to *Trematopygus* developed to a far greater extent. The four types surely illustrate a morphogenetic sequence. While petal-characters

appear to oscillate (save perhaps for steady reduction in the expansion of the petals), phyllode-development seems to show progressive (or, perhaps, regressive) modification. The plate-complexity that was concentrated into the true phyllodes of the older Nucleolitids (such as *Galeropygus* and "*Nucleolites*" *quadratus*) spread gradually away from the peristomial region until in area III of *Apatopygus* it involves the greater part of the area in triad-grouping. As far as phyllode-production is concerned, the change was catagenetic, but in respect of the complexity of the whole ambulacrum it was clearly anagenetic.

The sequence of ambulacral morphogenesis indicated above was carried out in a series of forms whose general evolution has been relatively static. Save for its ambulacral plating, *Apatopygus* would not have been out of place on a Middle Jurassic beach. Another line of descent from the *Galeropygus–Nucleolites* stock led in quite an opposite direction, and produced the *Clypeus–Pygurus* series with increasingly complex and limited phyllodes. That essentially Mesozoic group showed far more diversity in form, size, and detail than the conservative Nucleolitidæ, and paid the penalty of over-exuberance by extinction in the Cretaceous period. The two Nucleolitoid series thus provide clear illustration of the principles of evolution already familiar in many phyla. In comparison with Brachiopoda, *Apatopygus* may be said to bear a similar relation to *Galeropygus* to that borne by *Lingula* to *Lingulella*; while *Pygurus* would agree more with *Spirifer*. The persistent *Nautilus* and the extinct "*Ammonites*" have comparable histories.

The ambulacra of *Apatopygus* invite comparison with those of the Echinonëidæ. Save for the presence of petals and "biporous" orad ambulacrals, *A. recens* has typical Pyrinid ambulacral plating, almost perfect as far as it extends. In area I (Pl. VII, Fig. 1) there occur three Discoidiid triad-groups (similar plates appear in *Trematopygus*), so that the correspondence with Holectypoid structures is emphasized. It seems quite inconceivable that any phyletic link can connect *Apatopygus* with *Pyrina* or any other late Holectypoid; so that the appearance of Pyrinid plating in the recent form must be ascribed to parallel development.

If orthogenesis supplies an explanation of this coincidence, the separable qualities of the components of "individuals" is strikingly illustrated. The ambulacra of *Apatopygus* have come to conform to the Holectypoid standard in essentials (albeit by a non-Holectypoid route); while other coronal structures have followed quite different lines of development. Further, the appearance of Pyrinid plating in the last of the Nucleolitoida seems to give support to the belief that that stock branched from the Holectypoid series (though early) rather than arose independently. That extensive triad-grouping or combination after this pattern appeared in Lower Cretaceous times in the Echinina, Echinonëidæ, Lanieriidæ, and Nucleolitidæ, is a coincidence explicable only on the assumption

that morphogenesis may be not merely parallel in otherwise divergent stocks but proceeds at the same rate. Hence come "modes" or "fashions" prevalent in ultimately homogenetic series—sources of convenience to the stratigrapher and confusion to the systematist.

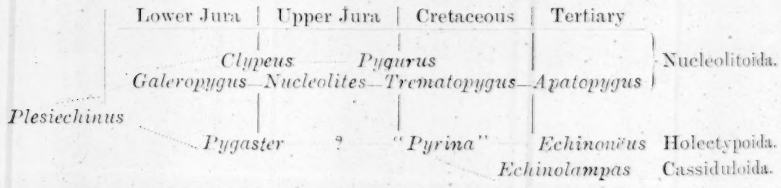
4. The Affinities of *Echinolampas*.

H. L. Clark (*Hawaiian and other Pacific Echini*, p. 143), commenting on my suggestion that the "Nucleolitidæ" (i.e. the Cassiduloidea of Sladen and Asternata of Gregory) may be diphyletic, states that "the recent species seem to form a very homogeneous group"; but he admits that "a more natural grouping in accordance with some of [my] suggestions" may prove possible. The earlier sections of this paper seem to me to show that *Apatopygus*, at least, is a very distinct type from the *Oligopodia–Rhynchopygus–Echinolampas* series of recent Cassiduloids. *Apatopygus* has definitely dissimilar petaloid pores—those of the Cassiduloida are similar and normally conjugate. I have no knowledge of any other living genus that can be associated with *Apatopygus* in the Nucleolitoida, and so agree with Clark as to the apparent homogeneity of his Nucleolitidæ with this single exception.

In several of the papers in this series, and especially in my recent memoir on ambulacra (Phil. Trans.), I have argued that the *Echinolampas*-series (which I call Cassiduloida *sens. str.*) are sequentially related to the early Echinonëidæ much as the Clypeastroida are to the Discoidiidæ. In the almost complete absence of knowledge of post-larval changes in recent Echinoids (zoologists, please note!), my arguments have necessarily been somewhat hypothetical or based on unverified assumptions. But in the section of Agassiz' Revision "On the young stages of Echini" (Part IV), p. 741, and in the plate (xvi) illustrative of the particular paragraph, something approaching ontogenetic proof of my contention appears. Agassiz says: "The development of *Echinolampas* has thrown unexpected light upon the affinities of the toothless Galerites and of the Cassidulidæ. It shows conclusively that *Echinonëus* is only a permanent embryonic stage of *Echinolampas*, thus becoming allied to the Cassidulidæ, and that it has nothing in common with the Galerites as I would limit them, confining them entirely to the group provided with teeth." These sentences were written long before Agassiz was able to record the presence of a vestigial lantern in young *Echinonëus*—in the light of that discovery the genus has almost everything "in common with the" Holectypoida. Study of Agassiz' drawings (pl. xvi, figs. 1–3) shows that *Echinolampas depressa*, when 4 mm. in diameter, is more like a *Conulus* or "*Globator*" than an *Echinonëus* in general facies, but has the tuberculation of a *Discoidea*. At a later stage, 12·7 mm. in diameter (tab. cit., figs. 8–10, here partly adapted, Pl. VII, Fig. 5), the test takes on a more depressed and elongate form, and the

tuberculation becomes amplified in the hour-glass pattern characteristic of *Conulus*. (In *E. sternopetala* Ag. & Clark, "*Conulus*-tuberculation" seems persistent even in the adult.) It is in the ambulacra, however, that the young *Echinolampas* exhibits the most remarkable qualities. Agassiz says of these (l.c., p. 742), "each plate . . . carries a single primary tubercle . . . The pores are arranged . . . three or four for each plate." His enlarged drawings (here Pl. VII, Fig. 5) show that "each plate" is really a triad-group. No indication appears as to the relations of the components of the groups, but that they are not all primaries seems probable from the nature of the perradial suture. In view of Agassiz' previously quoted remark, it is reasonable to assume that the triad-groups are Pyrinid in character, like those of *Echinonëus*. Such triadic structure is persistent in *Amblypygus* (otherwise very nearly akin to *Echinolampas*), but it is *not* retained in adults of *Echinolampas* itself. Its presence in early ontogeny must surely be vestigial. In consequence the descent of the *Echinolampas*-stock from an Echinonëid (or late Holectypoid) ancestry is a conception that is now so far established that it is for those who disagree to disprove it. Stratigraphy, morphology, and now ontogeny, all point to its truth.

The ambulacral history of the Nucleolitoida and Cassiduloida (assuming the above conclusions to be accurate) shows a strange course of morphogeny. The phyletic relations of the groups, as they appear to me, can be indicated thus:—



The Nucleolitoida early acquired elaborate phyllodes, retaining simplicity in the rest of their ambulacra. During the Mesozoic era their phyllodes underwent gradual decentralization, until triad-grouping affected a large part of the areas. This tendency culminates in *Apatopygus*. On the other hand, the Holectypoida failed to develop phyllodes, but progressively spread triad-grouping over their ambulacra (e.g. "*Pyrina*"). In the Tertiary era, simplification of plating, coupled with production of well-defined phyllodes (perhaps foreshadowed in *Conulus*), characterized the Cassiduloida. The two independent trends separated rapidly in the Lower Jurassic, and then slowly converged until, in the Cretaceous, they were almost coincident. Modern Cassiduloida have reached a stage analogous with that of the precocious Clypeidæ of the Nucleolitoida. But *Apatopygus* and *Echinonëus* remain as superannuated survivors, the last of their respective orders, wearing to-day the ambulacral fashions of the Cretaceous period.

EXPLANATION OF PLATE VII.

FIG. 1.—Analysis of ambulacrum I of *Apatopygus recens*, showing Pyrinid and Discoidiid plating below the ambitus, and dissimilarity of the petaloid pores. × c. 4.

FIG. 2.—Ambulacrum III of the same specimen, similarly enlarged. Pyrinid plating extends into the distal part of the petal.

FIG. 3.—Similar analysis of ambulacrum I of *Oligopodia epigonus*. An extremely simple phyllode is succeeded by "Bothriocidaroid" plates to the petal, which shows similar pores. This is a perfectly typical Cassiduloid ambulacrum, its phyllodal simplicity being probably due to the smallness of the species. × c. 6.

FIG. 4.—Ambulacrum III of the same specimen, similarly enlarged. Both areas have exactly comparable structure, and petals of precisely the same length.

(In these four figures the ambitus is indicated by small dashes.)

FIG. 5.—Part of corona of *Echinolampas depressa* at 12·7 mm. diameter. (Modified from A Agassiz, Revision, pl. xvi, fig. 11.) The interambulacral tuberculation is roughly like that of *Conulus*, but shows greater primitiveness in the scrobicular rings of granules. The ambulacral plates are grouped (or perhaps combined) into triads. The probable course of the sutures separating the individual plates is suggested by dotted lines (not present in the original figure). The triadic grouping shown (whatever its actual form) is clearly vestigial, since it is absent in adult forms. The pore-pairs seem in process of becoming single by loss of the outer member.

The Origin of Flint.

By R. M. BRYDONE, F.G.S.

MR. W. A. RICHARDSON'S paper in the December, 1919, number of this Magazine has furnished a very useful summary of the problem of the origin of flint, with some very interesting suggestions; but it cannot be allowed to pass altogether unchallenged.

It is a pity that he did not attempt to clear up the confused terminology of Chalk flint. There are, broadly, three kinds: separate flints in rows, interstratified continuous lines of flint, and contrastratified continuous lines of flint. Such terms as lines, bands, seams, layers, beds have been used indiscriminately of all three kinds. It is very desirable that some distinctive term such as "vein" should be attached to the third class, the continuous flint which at any part of its course breaks across the stratification; while "tabular" might be restricted to the interstratified continuous flint, and "row", a term which cannot suggest either vein or tabular flint, employed for lines of separate flints.

The paper is vitiated by the basic but very dubious assumption that all Chalk flint must have originated at the same time. Is it, in fact, conceivable that the interstratified rows of hollow flints can be all contemporaneous with the veins? These hollow flints practically always contain some amount of soft, loose powder, with an abnormal proportion of fossils in exceptional preservation, and a large majority have a loose spongiform nucleus. The formation and preservation of this assemblage seem to be

irreconcilable with any theory but that of the flinty envelope being practically contemporaneous with the chalk; the flint veins, some of which are nearly at right angles to the stratification, seem to be irreconcilable with anything like contemporaneous origin. Mr. Richardson states that "there is no difference between the two types of flint" (i.e. the bedded and the vein flint). Chemically and optically that has presumably been established for some vein or veins; but unless cavities containing powder, or wholly enclosed fossils, are commonly found in vein flint, and vein flint commonly occurs with a thick cortex, none of which things are within my experience, the statement can hardly be accurate as it stands.

A factor of considerable importance entirely overlooked by Mr. Richardson is to be found in the marl seams so abundant in the flinty chalk. These must be more impervious than the chalk, and would naturally hold up any downward diffusing or draining solution. But the relationship between marl seams and flint rows to which this would naturally give rise on Mr. Richardson's theory, i.e. marl seams coinciding with or just below flint rows, is almost unknown in practice. On the other hand, any advocate of a precipitation after gravitation theory might well appeal to the absolute freedom from marl seams of the great thickness of Thanet Chalk, whose silica, according to him, is now aggregated into the "Three Inch" band, and might also appeal to the disseminated marl in the Lower and Middle Chalk as the reason why no drainage aggregation of silica took place there. Incidentally it may be observed that the soft, spongy, dark-grey flints which are so abundant at Trimingham are characteristic of the marly chalk.

It is not safe to place much reliance on Mr. Richardson's table (No. 2) of silica contents. He budgets there for no less than twenty-two layers of 3 inches or more in thickness, containing 100 per cent of silica. When it is considered that the unique "Three Inch" band is no more than a layer 3 inches thick containing 100 per cent of silica, it will be seen how misleading an estimate must be which is based on the assumed presence of twenty-two "Three Inch" bands within the zone of *M. coranguinum* in Thanet (to say nothing of an assumed 12 in. band of solid silica in the zone of *Marsupites*). He has further budgeted for thirty layers of 3 inches, containing 50 per cent of silica, and therefore each the equivalent of a tabular $1\frac{1}{2}$ inches thick. If he will construct to scale any conceivable section of a layer 3 inches thick, of which 50 per cent shall be flint, he will see at once that such things are extremely rare in the Chalk, and that there cannot possibly be thirty of them in the Kent Coast section in addition to twenty-two "Three Inch" bands.

In his Fig. 4 he shows the *mucronata* chalk of Dorset as flintless, and in the text he states that in the *mucronata* zone the flints are generally small and immature. I do not know what his authority is, but I can assure him that at Studland, at any rate, the *mucronata* chalk of Dorset is by no means flintless, but contains strong rows

of massive and fully mature flints; so does the *mucronata* zone in the Isle of Wight at Alum Bay, and the *mucronata* zone of Norfolk on the Weybourn–Cromer coast, and also at Trimingham (in the white chalk).

Another point not touched on by Mr. Richardson is the frequency of horizontal uniformity in variations in the flints. Take, for instance, the flints of the upper part of the zone of *M. coranguinum* in Hants. In proportion as the *Uintacrinus*-band is approached, the white cortex encroaches on the clear interior and assumes a pink tinge, until the broken flints show nothing but pink cortex without any clear centre; and then it is time to look very closely for *Uintacrinus* if it has not already been found. Or take again the sponge-bed at Trimingham, which always has above and below it a bed of long slender flints like no others that I have seen. Such cases as these are much more suggestive of progressive formation of flints under varying conditions of the sea bottom than of simultaneous formation throughout many hundred feet of chalk in a more or less uniform set of conditions.

Mr. Richardson ignores the evidence of fossils, but there are several indications to be drawn from them. In the first place there are in the Chalk millions of specimens of *Echinocorys* perfectly filled with chalk. The only avenues by which this chalk could enter are the relatively minute apertures of the mouth and vent. It is clear that the ooze in which these shells were immersed after the animal's death must have been exceedingly fluid, practically liquid. With these chalk-filled *Echinocorys* there occur millions of *Echinocorys* perfectly filled with flint, yet having no vestige of flint on their outsides. Occasionally specimens of *Echinocorys* are found in which the interior is partly filled with chalk and partly with flint. In these cases there is always a definite boundary between the chalk and the flint. I have never seen any indication of sporadic silicification in the chalk inside an *Echinocorys*. These considerations seem irreconcilable with any metasomatic theory of the origin of the flint. In a medium so fluid as the ooze is shown to have been, nothing could have prevented it from filling those *Echinocorys* which are now silicified, except the presence of the dead body of the animal. As that decayed it must have been replaced by ooze unless the silica had already installed itself, and silica arriving at any later date would have found these *Echinocorys* completely filled with ooze. How are you going to arrange in a more or less consolidated deposit (on the uplift drainage theory a deposit hundreds of feet in thickness and almost necessarily consolidated) for the concentration on the two small apertures of a small proportion of the *Echinocorys* present in the chalk of streams of silica of exactly sufficient force, purity, continuity, and volume to displace every particle of chalk from the interior of these *Echinocorys* without the very slightest overflow of silica? The conclusion that the silica got there before the ooze had a chance seems irresistible. It is not difficult to see that the distinction

between the chalk-filled *Echinocorys* and the flint-filled *Echinocorys* might be due to the former having at the death of the animal come to rest with the apex downwards and the mouth and vent exposed, so that the dead body was cleared out by animalculæ and not left to decay, while the latter came to rest with the apex upwards and the mouth and vent pressed into the ooze, so that the dead body was left to decay and provoke the deposition of silica.

Again, the possibility that the flints were formed at the surface of the ooze can be written off altogether on fossil evidence. The Chalk sea was full of encrusting animals, such as *Spondylus latus*, *Ostreæ*, *Serpulæ*, and *Porosphæræ*. I have never seen a case, and I do not know of one having been recorded of any organism being found encrusting a flint, though that must have happened freely if they had existed at the surface of the ooze. It is rather surprising that the suggestion should ever have been made, for it must be plain that as soon as a particle of flint had formed at the surface it would, owing to its specific gravity, sink out of sight at once in the practically liquid ooze. It would presumably sink to such a depth as the consolidation of the ooze, naturally increasing with depth, would admit, and might there form a nucleus for concretionary growth of a flint. All particles of flint arising at the surface of the ooze about the same time would presumably sink to about the same depth, which might quite well be below the range of a dredge, and would give rise to a row of flints roughly parallel with the surface of the ooze, i.e. pseudo-stratified. A question here suggests itself which I am unable to answer, i.e. whether the specific gravity of a solution of silica might be sufficient to produce the same result by a concentration of the silica in solution at some depth below the surface of the ooze where precipitation would occur, and the newly precipitated flints would then sink to their natural static level.

Again, it is a well-known thing that fossils of all descriptions are frequently embedded in flints. I have not made any express test, but it is my strong impression that fossils are much more abundant at the periphery of flints than at any other internal contour-line, or, indeed, in the whole of the interior. It is possible to regard these external fossils as having contributed to determining the outline of the flints by some power of attraction of the growing amorphous mass of colloid silica, and the most likely cause of such an attraction would be the presence on them of decaying animal matter, which would involve penecontemporaneous formation of the flint.

Again, as I have indicated above, the contents of hollow flints afford a strong argument for the contemporaneous or penecontemporaneous origin of these flints, at any rate.

On the whole a penecontemporaneous origin for row and tabular flints seems to present the minimum of conflict with facts, while the vein flint is obviously of some subsequent date at or after the formation of the uplift cracks which it occupies.

The Distribution of British Carboniferous Nautiloids.

By the late WHEELTON HIND, M.D., F.R.C.S., F.G.S.

WITH the exception of the Catalogue of Fossil Cephalopoda by Foord in the British Museum (Natural History) and the same author's monograph *Carboniferous Cephalopoda of Ireland*, the bibliography of this family as represented in Carboniferous time is scattered through many volumes and publications. Not one of the publications makes any attempt to define the precise horizon in the Carboniferous Series at which any one of the species occurs, or indicates its persistence in geological time.

It does not seem to be at all probable that the Nautiloids will lend themselves as zone indices, in the way in which Ammonoids do from Carboniferous to Jurassic times. On the other hand, Nautiloids are well distributed throughout the Carboniferous Series, and some species at least are confined to definite horizons. Hyatt's classification of Cephalopod genera was adopted by Foord in his monograph, and is followed in this paper.

The table of distribution of British Carboniferous Nautiloids shows that a comparatively large number of them are found in the Millstone Grit and Upper Coal-measures, while the Pendleside Series only possesses three species. The Carboniferous Limestone and the Upper Dibunophyllum beds are fairly rich, and there is an horizon very rich in them in the Upper Caninia beds of Ireland and Kniveton. Little Island, co. Cork, must contain some beds of Upper Dibunophyllum age, as demonstrated by the presence of *Cœlonautilus planotergatus*, *Stroboceras sulcatum*, *Vestinautilus crassimarginatus*.

TABLE SHOWING DISTRIBUTION OF BRITISH CARBONIFEROUS NAUTILOIDS.

COAL-MEASURES.

Temnocheilus carbonarius Foord.
tuberculatus Sow.
concavus J. de C. Sow.
Ephippioceras wildi Hind.
clitellarium J. de C. Sow.
costatum Foord.
Pleuronautilus pulcher Crick.
costatus Hind.
P. falcatus J. de C. Sow.
armatus J. de C. Sow.
rotifer Salter.
Cœlonautilus raveseni Inglis.
Stroboceras quadratus Fleming.
Solenocheilus cyclostomus Phillips.
globosus Hind.
Cyclonautilus umbilicatus Hind.

MILLSTONE GRIT.

Temnocheilus tuberculatus Sow.
Pleuronautilus pulcher Crick.
nodosocarinatus F. Römer.
Ephippioceras bilobatum Sow.
Stroboceras sulcatum J. de C. Sow.
Solenocheilus globosum.
cyclolobum.

PENDLESIDE SERIES.

Phacoceras oxystomum Phillips.
Stroboceras quadratum Fleming.
Thrincoceras luidii Martin.

Upper Carboniferous Limestone – Upper Dibunophyllum Zone.

Temnocheilus coronatus M'Coy.
derbiense Hind.
costato-coronatus M'Coy.
Pleuronautilus scarlettensis Reid.
Ephippioceras bilobatum Sow.
Stroboceras sulcatum J. de C. Sow
bisulcatum de Koninck.
Discitoceras leveilleanum de Koninck.
wrightei Foord.
Apheleceras latum Hind.
Vestinautilus crassimarginatus Foord.
Cœlonautilus planoterqatus Phillips.
Coloceras bistriale M'Coy.
Thrincoceras luidii Martin.
Solenocheilus caledonicus Foord.
cyclostomus Phillips.
clausus Foord.
crassicenter de Koninck.
infundibulum de Koninck.
ingens Martin.
derbiensis Foord.

Lower Carboniferous Limestone (probably *Caninia*).

Trigonoceras paradoxicum J. de C. Sow.
Discitoceras leveilleanum de Koninck.
discors M'Coy.
costellatum M'Coy.
Apheleceras mutabile M'Coy.
hibernicum Foord & Crick.
discus Sow.
Mesochasmoceras latidorsatum M'Coy.
Diorugoceras planidorsatum Portlock.
Triboloceras formosum Foord.
Vestinautilus semiglaber Foord.
cariniferus J. de C. Sow.
crateriformis Foord.
pinguis de Koninck.
V. paucicarinatus Foord.
multicarinatus J. de C. Sow.
Cœlonautilus doohylensis Foord.
gradus Foord.
Planetoceras globatum J. de C. Sow.
Coloceras coyanum d'Orbigny.
bistriale M'Coy
Thrincoceras hyatti Foord.
hibernicum Foord.
Aipoceras compressum Foord.
Asymptoceras crassilabrum Foord
foordi Hyatt.
Solenocheilus dorsalis Phillips.
hibernicus Foord.

Temnocheilus M'Coy, 1844.

Type.—T. coronatus M'Coy, 1844, Syn. Carb. Foss. Ireland.

Temnocheilus coronatus M'Coy.—Upper Dibunophyllum zone. Lowick, Northumberland; Parwich and Castleton, Derbyshire; Stebden Hill, Yorkshire. Little Island, co. Cork, Ireland. Visé, Belgium.

T. tuberculatus Sow., 1821.—Dibunophyllum zone to Lower Coal-measures. Lower Coal-measures, Shibden and Halifax, Yorkshire; Sabden Shales, Rough Lee, Lancashire; Silica Quarry, Congleton Edge (= Sabden Shales), Cheshire. Closeburn, Dumfriesshire, Scotland.

T. concavus J. de C. Sow., 1840.—Coal-measures. Coalbrookdale; N. Staffs; Lancashire. S. Wales.

T. carbonarius Foord, 1891.—Coal-measures. Coalbrookdale; N. Staffs; Lancashire.

T. derbiense Hind.—Upper Dibunophyllum zone. Tissington, Derbyshire.

T. cricki Foord.—Described in the Catalogue of the Natural History Museum; from Ireland ? but without any definite locality. Was ignored by Foord in his later monograph.

T. costato-coronatus M'Coy. — ? 4 Laws Limestone, Lowick, Northumberland.

T. tuberosus M'Coy —Derbyshire.

TRIGONOCERAS M'Coy, 1844.

Type.—*T. paradoxicum* J. de C. Sow., 1825, Min. Conch., vol. v, p. 81, pl. ccccIvii.

Trigonoceras paradoxicum J. de C. Sow.—Carboniferous Limestone, C_1. St. Doolaghs, co. Dublin; Clane, co. Kildare; Rathkeale and Doohyle, co. Limerick; Cork, Ireland. *Fide* De Koninck, Visé, Belgium.

PLEURONAUTILUS Mojsisovics.

Pleuronautilus falcatus J. de C. Sow.—Coal-measures. Rosser Veins, Glan Rymney, S. Wales; Pennystone, Shropshire. Millstone Grit (Sabden Shales), Sale Wheel, River Ribble, Lancashire.

P. armatus J. de C. Sow.—Coal-measures. Pennystone, Shropshire.

P. costatus Hind.—Coal-measures. Below Gin Mine Coal, N. Staffs; 705 feet above the Barnsley Coal at Brodsworth, Yorkshire.

P. pulcher Crick.—Millstone Grit to Coal-measures, Sabden Shales horizon, Horsebridge Clough, near Hebden Bridge; 71 feet below the 4 ft. Coal, Cheadle, N. Staffs.

P. rotifer Salter.—This species is probably identical with *P. falcatus* J. de C. Sowerby. 150 yards above the Great Mine Coal, River Tame, Ashton-under-Lyme.

P. nodosocarinatus F. Romer. Range, Dibunophyllum zone to Millstone Grit.

SYN. *Nautilus nodiferus* Armstrong, Trans. Geol. Soc. Glasgow, vol. ii, pt. i, p. 74, pl. i, figs. 6–7.
Pleuronautilus nodosocarinatus Foord, GEOL. MAG., 1891, p. 481, with woodcut.

Marine Band, Caton Green, Lancashire; below Little Limestone, Smith's Grit, near Hawes, Swaledale, Yorkshire. U.L.S., Castlecary, Arden, Barrhead, Garngad Road, Gare, Westerhouse; L.L.S., East Kilbride, Scotland.

P. scarlettensis Reid.—Top of Upper Dibunophyllum zone or base of Pendleside Series. Scarlet Quarry, Isle of Man.

EPHIPPIOCERAS Hyatt.

Type.—*E. ferratus* Cox, Coal-measures, Kentucky, U.S.A.

Ephippioceras bilobatum Sow.—Upper beds of Carboniferous Limestone to Coal-measures. The Caytongill Beds of Sawley, near Ripon, Yorkshire; 4 Laws Limestone, Combe, Northumberland; below the 3rd Grit, Congleton Edge, Cheshire; Castletown Limestones, Isle of Man. Carboniferous Limestone, Closeburn, Dumfriesshire, Scotland.

E. clitellarium J. de C. Sowerby.—Coal-measures. Pennystone Bed, Shropshire; Marine band above the Barnsley Coal, Yorkshire.

E. costatum Foord.—Coal-measures. Pennystone Bed, Shropshire; below the Gin Mine Coal, N. Staffs; Leicestershire.

E. wildi Hind.—Coal-measures. Above the Bullion Coal, Carreheys (near Colne), Burnley, Shere (near Littleborough), and Sholver (near Oldham), Lancashire.

STROBOCERAS Hyatt.

Type.—S. hartii Dawson, Acad. Geol., 3rd ed., p. 311, fig. 125.

Stroboceras sulcatum J. de C. Sow.—Upper Dibunophyllum zone of Carboniferous Limestone to Millstone Grit. 4 Laws Limestone, Combe, and Redesdale Ironstone, Northumberland; Millstone Grit, Cleul Quarries, and Pendleside Series, Burnsall, Yorkshire; D, River Ribble, and Sabden Shales, Rough Lee, Lancashire; near Kirkby Lonsdale, Westmorland; Castleton, Bradbourne, and Chrome Hill, Derbyshire; Poolvash, Isle of Man. In Scotland specimens are mixed with *S. quadratus* Flem., which is regarded as a synonym. Little Island, co. Cork; Mullaghfarry and Crosspatrick, Killala, co. Mayo; Carnteel, co. Tyrone, Ireland. Visé, Belgium.

S. crassum Foord.—Ring near Enniskillen, co. Fermanagh, Ireland.

S. bisulcatus de Koninck.—Upper Dibunophyllum zone. Swindon Quarry, near Cracoe, Yorkshire; Parwich, Irey Cliff, and Castleton, Derbyshire. Visé, Belgium.

S. quadratus Fleming.—Coal-measures; Pendleside Series; U.L.S., Scotland. Coal-measures of Shropshire (Pennystone Beds); Lowick and Redesdale Ironstone, Northumberland. Roscobie, Fife, and in neighbourhood of Glasgow, Scotland. Foynes Island, Ireland.

DISCITOCERAS Hyatt.

Type.—D. costellatum M'Coy.

Discitoceras leveilleanum de Koninck.—Castleton, Derbyshire; Scarlet Quarry, Isle of Man. Clane and Naas, co. Kildare, Ireland.

D. discors M'Coy.—Askeaton, co. Limerick.

D. wrightii Foord.—Upper Dibunophyllum horizon. Poolvash, Isle of Man. Little Island and Middleton, co. Cork, and Askeaton, co. Limerick, Ireland.

D. costellatum M'Coy.—Milicent and Clane, co. Kildare, Ireland.

PHACOCERAS Hyatt.

Type.—P. oxystomum Phillips.

Phacoceras oxystomum Phillips.—Probably base of Pendleside Limestone. Hodder Place, Lancashire; Lowick (M'Coy), Northumberland; Poolvash, Isle of Man. Florence Court, Enniskillen (Phillips), and Drumscraw, Tyrone (M'Coy), Ireland. Visé, Belgium.

P. ? rectisuturale Foord.—Co. Kildare.

APHELECERAS.

Type.—A. mutabile de Koninck.

Apheleceras mutabile M'Coy.—Upper Caninia zone. Kniveton, Derbyshire. Rathfarnham, co. Dublin, Clane and Naas, co. Kildare, Rathkeale, co. Limerick, Little Island, co. Cork, and Cregg, co. Meath, Ireland. Anseremme, Belgium.

A. hibernicum Foord & Crick.—St. Doolaghs, co. Dublin, Ireland.

A. trochlea M'Coy.—Probably C or S horizon. Kendal. Cookstown, co. Tyrone, Ireland.

A. latum Hind.—Upper Dibunophyllum zone. 4 Laws Limestone, Combe, Northumberland.

A. discus Sow.—Probably C or S horizon. Kendal.

MESOCHASMOCERAS Foord.

Mesochasmoceras latidorsatum M'Coy.—Clane, co. Kildare, and Argone South and Cragard, co. Limerick, Ireland.

DIORUGOCERAS Hyatt.

Diorugoceras planidorsatum Portlock.—Derrylorran, Tyrone, Ireland.

TRIBOLOCERAS Hyatt.

Type.—T. serratum de Koninck.

Triboloceras formosum Foord.—*Seminula* zone. From the Crinoid Bed, Slaidburn, Yorkshire. Lisbane, co. Limerick, and Garrikies, co. Kerry, Ireland.

VESTINAUTILUS de Ryckholt, 1852, emend. Hyatt.

Type.—V. koninckii d'Orbigny.

Vestinautilus semiglaber Foord.—Lisbane, co. Limerick, Ireland.

V. crassimarginatus Foord.—Upper Dibunophyllum zone. Parwich, Derbyshire. Little Island, co. Cork, Ireland.

V. cariniferus J. de C. Sowerby.—C. S_1. Thornley Quarry, near Chipping, Lancashire. Clane, co. Kildare, Enniskillen, co. Fermanagh, Rathkeale and Ardtomen, co. Limerick, Ireland.

V. crateriformis Foord.—C.-S. Clitheroe, Lancashire; Kniveton, Derbyshire. Rathkeale, co. Limerick, Ireland.

V. pinguis de Koninck.—Kniveton, Derbyshire. Cloghran and St. Doolaghs, co. Dublin, and Askeaton, co. Limerick, Ireland.

V. paucicarinatus Foord.—St. Doolaghs, co. Dublin, Clane, co. Kildare, Little Island, co. Cork, Ireland.

V. multicarinatus J. de C. Sowerby.—Kniveton, Derbyshire.

CŒLONAUTILUS Foord, emend. Hyatt.

Type.—C. planotergatus M'Coy.

Cœlonautilus planotergatus M'Coy.—Upper Dibunophyllum zone. Thorpe Cloud, Castleton, Bradbourne, and Pindale, Derbyshire; Withgill, Lancashire; 4 Laws Limestone, Combe, Redesdale, Northumberland; Elbolton, Craven, Yorkshire; Poolvash, Isle of Man. Little Island, co. Cork, and Rathkeale, co. Limerick, Ireland. Visé, Belgium.

C. rawsoni Inglis.—Lower Coal-measures. Above the Bullion Coal, Burnley, Lancashire; above the Bullion Coal, Halifax and Shebden, and Millstone Grit Series of Eccup and Marsden (Pale Hill), Yorkshire. *C. trapezoidalis* W. Jackson is a synonym.

C. doohylensis Foord.—Elbolton, Yorkshire. Doohyle, near Rathkeale, Ireland.

C. gradus Foord.—? Clane, co. Kildare, and Rathkeale and Curraghbridge, co. Limerick, Ireland.

PLANETOCERAS Hyatt.

Planetoceras globatum J. de C. Sow.—Horizon C_1. St. Doolaghs, co. Dublin, Kildare, and Doneraile, co. Cork, Ireland. A very much misunderstood fossil; few authors have correctly referred specimens to this genus.

COLOCERAS Hyatt.

Coloceras coyanum d'Orbigny.—C.-S. horizon. Kilmallock and Rathkeale, co. Limerick, and Ballyduff, co. Waterford, Ireland. De Koninck quotes the species from Visé, Belgium.

C. bistriale Phillips.—Poolvash, Isle of Man. Clane, co. Kildare, and Tourdeely, co. Limerick, Ireland. Woodmill, Dunfermline, U.L.S., Scotland. The distribution of this species requires further examination, and the Irish examples are from Lower Carboniferous beds and the British from higher only.

THRINCOCERAS Hyatt.

Thrincoceras hyatti Foord.—St. Doolaghs, co. Dublin.

T. hibernicum Foord.—Glenbane, co. Limerick.

T. luidii Martin.—Narrowdale, Staffs; and the Limestones of Pendleside horizon, Longstone, Derbyshire; Hodder, Lancashire; Elbolton, Yorkshire. Lady McLaren's Quarry, near Prestatyn, Wales.

AIPOCERAS Hyatt.

Aipoceras compressum Foord.—Horizon C. Clane, co. Kildare, Ireland.

ASYMPTOCERAS Ryckholt, 1852, emend. Hyatt, 1883–93.

Asymptoceras crassilabrum Foord.—Clane, co. Kildare.

A. foordi Hyatt.—Clane, co. Kildare, and Rathkeale, co. Limerick.

SOLENOCHEILUS Meek & Worthen, emend. Hyatt, 1883–93.

Solenocheilus Phillips.—C.-S. Salt Hill and Bellman Quarries, Clitheroe, Lancashire. St. Doolaghs, co. Dublin, Clane, co. Kildare, Rathkeale and near Askeaton, co. Limerick. Black Rock and Little Island, co. Cork, *fide* Griffiths.

S. hibernicus Foord.

SYN. *Acanthonautilus bispinosus* Foord.

Clane, co. Kildare, and ? Little Island, co. Cork.

S. clausus Foord.—Little Island, near Cork; probably D.

S. caledonicus Foord.—Elbolton, Yorkshire. Arden Quarry, Nitshill, Glasgow, and Roscobie, Fife, Scotland.

S. cyclostomus Phillips.—Millstone Grit, Horsebridge Clough, and High Green Wood at the horizon of the Sabden Shales; Crowdecote, Derbyshire. Axton, N. Wales.

S. crassiventer de Koninck.—The Little Limestone, Weardale; (var.) Castleton, Derbyshire.

S. infundibulum de Koninck.—Upper Beds of Dibunophyllum zone at Elbolton, Yorkshire; Hollington End, Derbyshire.

S. ingens Martin.—Upper beds of the Dibunophyllum zone.

Syn. *Solenocheilus pentagonalis* Phillips.

Little Limestone, Weardale, Durham; Bradbourne and near Ashford, Derbyshire; Astbury Old Quarry, Cheshire. Bathgate, Linlithgowshire, Closeburn and Kirtlebridge, Dumfriesshire, and Arden Quarry, Nitshill, Scotland.

S. derbiensis Foord.—Upper Dibunophyllum zone. Park Hill, Castleton, and Crowdecote, Derbyshire; Narrowdale, Staffs; 4 Laws Limestone, Combe, Northumberland; Poolvash, Isle of Man. I do not consider the variety named *S. derbiensis* var. *globularis* of Foord sufficiently distinct to be retained.

S. globosus Hind.—Millstone Grit, Lower Coal-measures. Caton; Sales Wheel, River Ribble; Bullion Coal, Carreheys, near Colne, Burnley Coalfield, Lancashire; the marine bed, Silica Quarry, Congleton Edge, Cheshire.

Cyclonautilus Hind.

Cyclonautilus umbilicatus Hind.—Coal-measures. Roof of the Bullion Coal, Burnley.

On the Investigation of the Mechanical Constitution of Loose Arenaceous Sediments by the method of Elutriation, with special reference to the Thanet Beds of the Southern Side of the London Basin.

By Herbert Arthur Baker, M.Sc., F.G.S.

(*Continued from p. 370.*)

Leading Characteristics of Elutriation-Curves of Sediments.

WITH regard to the laws governing the transport, sorting, and deposition of sediments, much has still to be learned, but one fact emerges clearly from the mass of present data. During the process of transport by water the load undergoes selective treatment, or, in other words, is sorted. The late Dr. G. K. Gilbert, in the course of his important work on the transportation of débris by running water,[1] carried out experiments with mixtures of several grades of detrital material and found that before the slope of the stream had been definitely established (i.e. before the attainment of uniformity of conditions), and especially when low velocities were used, the current tended to sort the débris, building deposits with the coarser part and continuing to transport the finer material. This fact has a special bearing on the study of natural sediments. The state of equilibrium, or of perfect uniformity of conditions, is seldom, if ever, completely realized in nature, and even when approximately reached is not, as a rule, of long duration. Further, in general, the detrital

[1] Gilbert, "The Transportation of Débris by Running Water": U.S. Geol. Surv. Professional Paper 86, 1914.

deposits of the geological column are the results of transport by and deposition from comparatively slow-moving currents. Deposits of torrential character are exceptional. Consequently, we should expect to find far-travelled natural sediments, which have been subjected to long-continued aqueous action before deposition, showing in a marked degree the results of selective treatment, and sediments deposited after a short career under transport showing very little evidence of sorting. The material composing arenaceous sediments deposited under marine conditions must, in general, have had an earlier history, during which it formed part of fluviatile or estuarine deposits, and in view of the greater vicissitudes experienced should show the results of selective action in a high degree. On the other hand, a deposit such as a fluviatile loam or brickearth, deposited after only a short career under transport, and not having been subjected to any special type of selective action, should show a marked absence of sorting. The expectation is verified. Fig. 3 shows, for purposes of comparison, the typical elutriation-curves yielded by fluviatile, estuarine, and marine sediments. In the case of the fluviatile deposit, its immaturity, from the point of view of its modification under aqueous action, is shown by the curve by the marked absence of a "hump" and by the very low grading factor. The marine sediment yields a curve with a pronounced "hump" and gives a much higher grading factor. The estuarine sediment is of intermediate type. Many more examples might be given to show the soundness of this generalization, but they are scarcely necessary at this point.

Mechanical Constitution of the Thanet Beds of the Southern Side of the London Basin.

The following summary of the leading features of the mechanical constitution exhibited by the Thanet Beds is based upon the results of a very large number of analyses of samples from a widespread area.

Everywhere along the southern side of the London Basin the Thanet Beds are always progressively coarser from the base upwards. A sample from the upper part of the Thanet Beds in any locality will always yield a higher Equivalent Grade factor than will another taken from a lower level. Samples taken from similar horizons in different localities do not, however (unless the localities are only a mile or two apart), yield corresponding figures. The Thanet Beds become finer in grain as we proceed both eastward and westward from the type district of West Kent. The Thanet Beds of East Kent, as shown by the sections at Pegwell Bay and Herne Bay, are the most fine-grained representatives of these deposits in the southern part of the London Basin (see Fig. 4). It is only, however, in the upper part of the beds that the transition from coarser to finer material, eastward and westward of West Kent, is steadily progressive. The lower part shows greater variation. The lower portion of the beds in the West Kent type area shows finer sediments

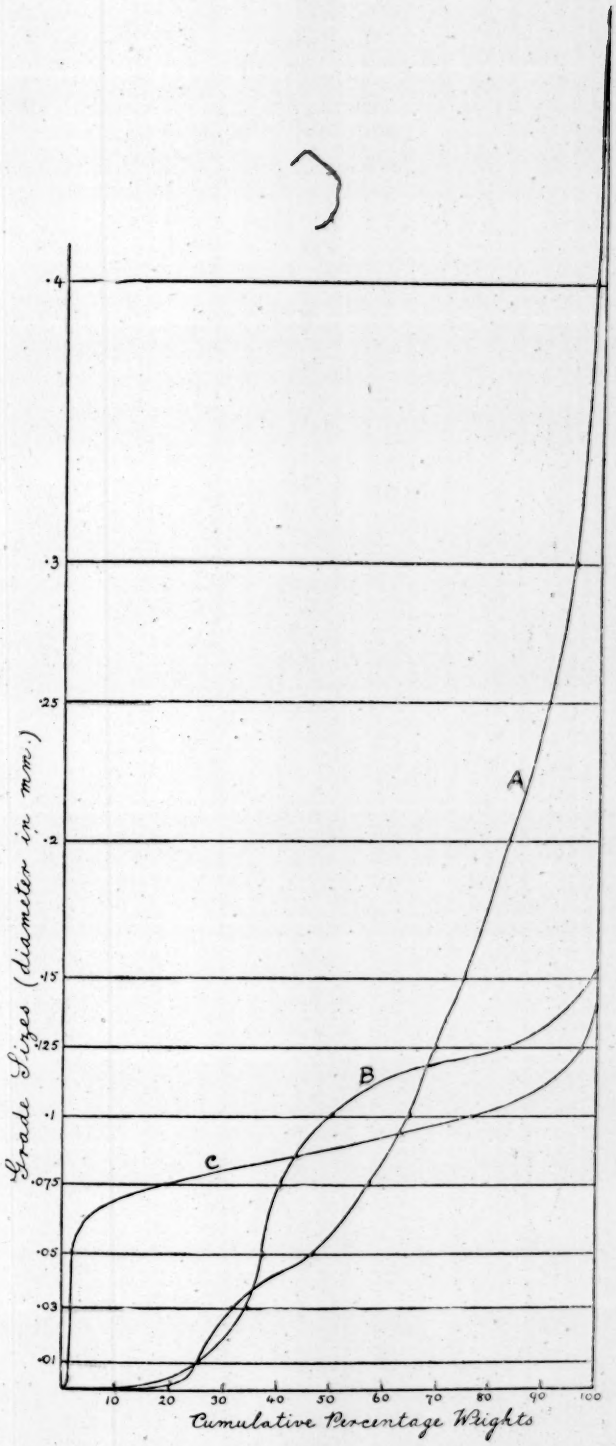


FIG. 3.—Types of elutriation curves of arenaceous sediments.

A. Fluviatile. Pleistocene Loam, Cray Valley, Foot's Cray. E = ·095 mm., G = ·140.

B. Estuarine. Woolwich Beds, Charlton; greenish loamy basement-bed. E = ·075 mm., G = ·347.

than those at corresponding horizons anywhere to the west and for many miles eastward. The Lower Thanet Beds of East Kent are, however, finer than the finest sediments of the West Kent sequence. Some of the very fine, indurated, muddy sediments of Pegwell Bay proved so refractory in the laboratory that no mechanical analysis was possible. The West Kent type of Thanet Beds shows the greatest amount of variation in mechanical constitution seen in these beds anywhere in the London Basin, the Equivalent Grade factor ranging from ·059 mm. at the base of the deposit to ·146 mm. at the top. The evidence suggests that early in Thanetian times special conditions obtained in the West Kent area, whereby loamy and silty beds, not possessing in any marked degree the

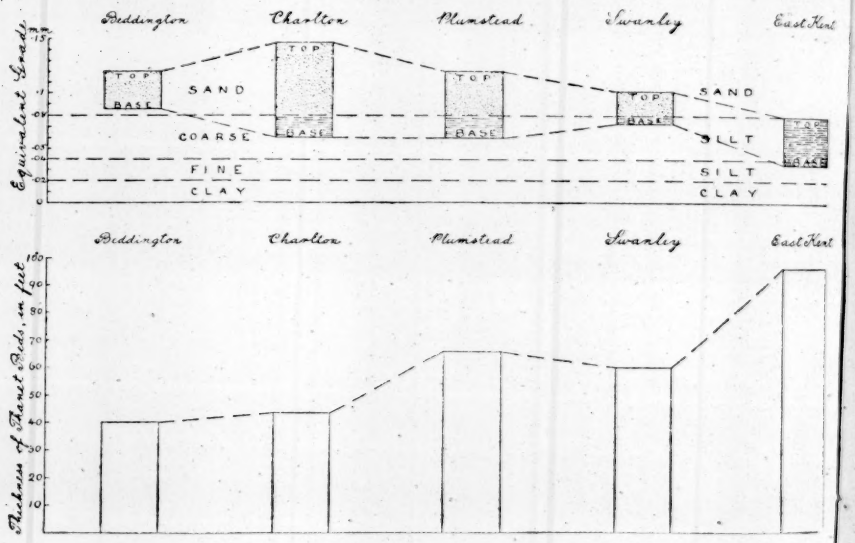


FIG. 4.—Diagram showing thickness of Thanet Beds and range in mechanical constitution, for various localities, from west to east, along the southern side of the London Basin.

characteristics of marine sediments, were being deposited locally, somewhat before the definite establishment of typical marine conditions. From the fact that the lower Thanet Beds eastward and westward of West Kent (excluding the East Kent area) are fairly well-sorted sediments, giving elutriation-curves of marine type, one is tempted to hazard the conjecture that the lowest beds in West Kent may be older than these.

Thickness of deposit, together with narrow range of variation in mechanical constitution, may be taken to indicate approximate uniformity of conditions of sedimentation, and comparative paucity of sediment with considerable lithological variation, the reverse.

Fig. 4 indicates the comparative instability of conditions of sedimentation in West Kent during the deposition of the Thanet Beds.

The diagram (Fig. 5) shows the rough, provisional classification of arenaceous sediments based upon values of Equivalent Grade and Grading Factor, in use by the writer. The value of the Equivalent Grade factor decides whether a sediment shall be classified as a sand, a silt, or a clay, the limit between sands and silts being taken at ·08 mm., and that between silts and clays at ·02 mm. The value of the Grading Factor decides whether a sediment shall be classified as a true sand or silt, or as a loam, since the characteristic of the loams is the low value of the Grading Factor. The limiting value of the Grading Factor which separates sands and silts on the one hand from loams on the other, is taken at ·6. The classification seems to answer very well.

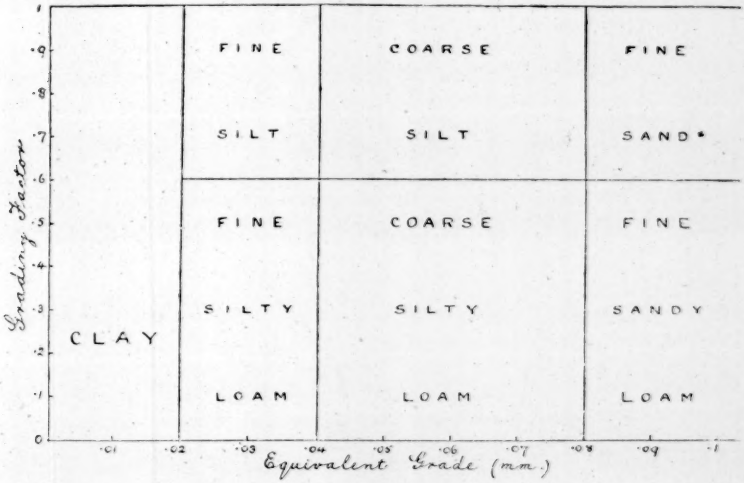


FIG. 5.—Provisional classification of the finer arenaceous sediments, based on Equivalent Grade and Grading Factor values.

Fig. 6 shows types of elutriation-curves yielded by the Thanet Beds of various localities along the southern side of the London Basin, and the table at the end of the paper gives a selection from a large number of mechanical analyses obtained by the writer.

The construction of a graph showing the relation between the Grading Factor and Equivalent Grade yields results of remarkable interest in the case of the Thanet Beds. When a series of field samples are taken from successive levels in the Thanet Beds at any one locality and mechanical analyses are carried out and the related values of Grading Factor and Equivalent Grade are plotted on a graph, it is found that the points obtained show a strong tendency to lie on a straight line. What is even more remarkable, however,

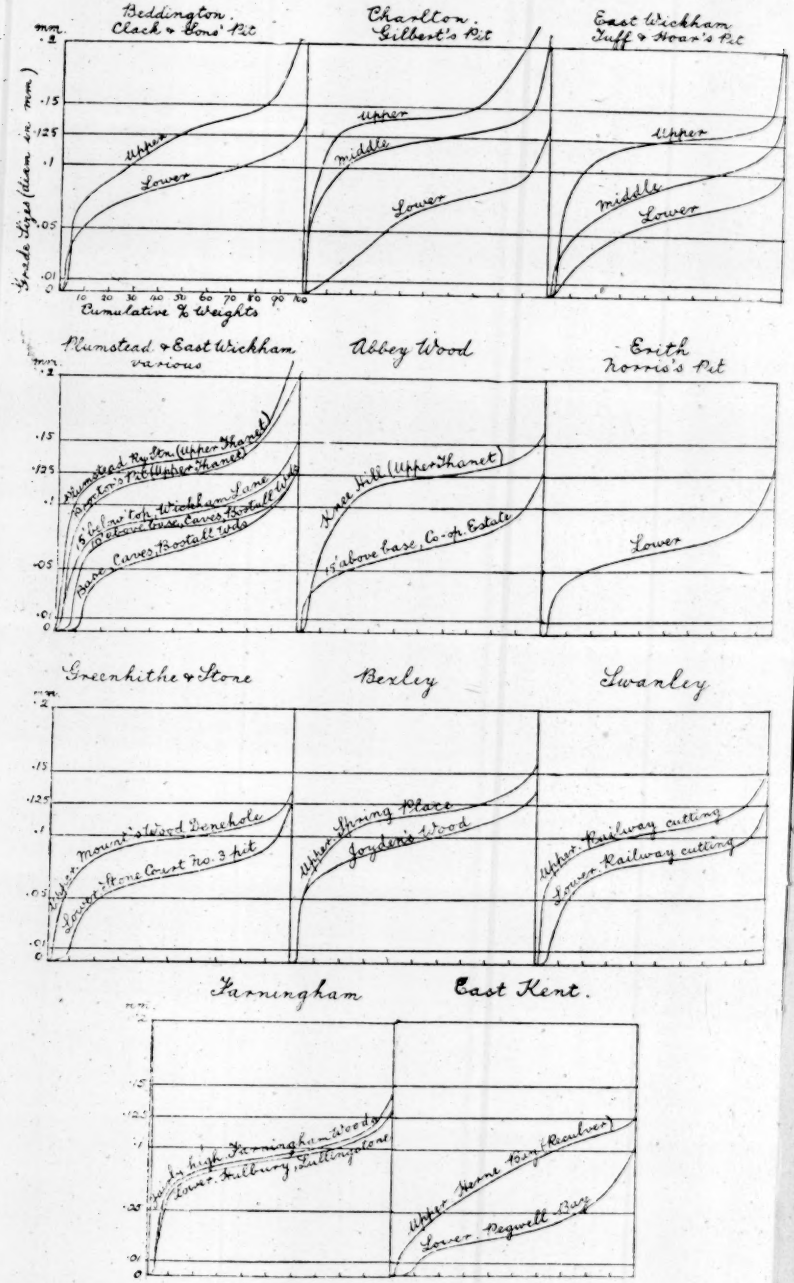


FIG. 6.—Elutriation curves (much reduced) of Thanet Beds of southern side of London Basin.

is that if this be done for a series of localities, the series of straight lines obtained show a strong tendency towards parallelism. (See Fig. 7.) This signifies that in the case of the Thanet Beds there is a tendency towards a simple linear relation between change of Equivalent Grade and change of Grading Factor. On investigating this point the writer was able to obtain the following remarkable result connecting two samples of the Thanet Beds:—

If sample 1 has Equivalent Grade E_1 and Grading Factor G_1 and sample 2 has Equivalent Grade E_2 and Grading Factor G_2, then $G_2 = G_1 \pm 2{\cdot}56\ (E_2 \sim E_1)$.

Take + sign when $E_2 > E_1$ and − sign when $E_2 < E_1$.

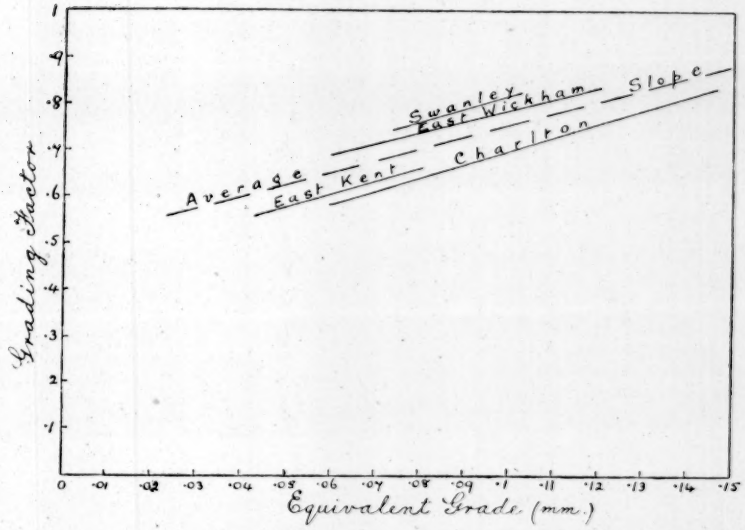


FIG. 7.—Graph showing the relation between Equivalent Grades and Grading Factors of Thanet Beds material from various localities.

This evidence of steady change in the lithological character of the sediments with concomitant change in the degree of sorting of the material signifies the establishment of conditions under which more and more highly sorted material was being deposited. The degree of sorting of a sediment is probably, in general, a cumulative effect depending upon the total vicissitudes through which it has passed, and these vicissitudes are greatest in the case of material which, originally derived from the denudation of a land-area, has passed successively through the stages of having been incorporated in fluviatile and estuarine sediments and has finally been deposited under marine conditions. In the striking feature of the Thanet Beds to which allusion has been made, we have, perhaps, the sign of the gradual and definite establishment of marine conditions.

TABLE OF MECHANICAL ANALYSES OF THANET

Locality, etc.	Clay Grade.	Silt Grades.	
		Fine Silt.	Coarse Silt.
	< ·01 mm.	> ·01 mm. < ·05 mm.	> ·05 mm. < ·1 mm.
	% wt.	% wt.	% wt.
Beddington, Surrey. Clack & Sons' pit. Upper part of Thanet Sand	2·37	2·25	23·97
Beddington, Surrey. Clack & Sons' pit. Lower part of Thanet Sand	0·20	9·40	64·65
Charlton. Gilbert's pit. Upper Thanet Sand	1·45	0·67	3·97
Charlton. Gilbert's pit. Lower Thanet Beds (Blackfoot).	9·52	24·17	58·98
Plumstead Station. Upper part of Thanet Sand	2·57	1·50	5·28
Plumstead. Proctor's pit, east of Plumstead Common. Upper part of Thanet Sand	4·75	0·90	10·30
East Wickham. Tuff & Hoar's pit. Thanet Sand, upper part	3·72	1·58	8·48
East Wickham. Tuff & Hoar's pit. Thanet Sand, middle part	0·78	11·54	59·68
East Wickham. Tuff & Hoar's pit. Thanet Beds, lower part	2·90	26·20	70·90
East Wickham. Wickham Lane Bricktield. Thanet Sand, about 15 feet below junction with Woolwich Beds	4·28	4·92	59·66
The "Caves", East Wickham Valley. Lower Thanet Beds, about 10 feet above Bullhead Bed	8·24	3·24	75·54
The "Caves", East Wickham Valley. Lower Thanet Beds, immediately above Bullhead Bed	13·12	14·20	62·16
Abbey Wood. Roadside section, Knee Hill. Upper Thanet Sand, immediately below Woolwich Beds	5·64	2·37	12·10
Abbey Wood. Co-operative Society's Estate. Thanet Beds, about 15 feet above base	2·00	18·24	72·24
Old Bexley. Spring Place, Dartford Lane. Roadside section in Upper Thanet Sand	3·42	0·92	16·05
Erith. Norris's pit. Lower part of Thanet Beds	1·85	14·36	74·40
Joyden's Wood, near North Cray. Thanet Sand, about middle of deposit	3·07	1·65	51·17
Farningham Woods, southern part. Thanet Sand, fairly high up in deposit	4·40	2·02	58·70
Swanley. Railway cutting between Swanley Junction and Farningham Road Station. Thanet Sand, upper part.	2·17	1·55	32·85
Swanley. Railway cutting between Swanley Junction and Farningham Road Station. Thanet Beds, lower part	6·27	7·72	76·77
Stone. Stone Court, No. 3 pit, west of Cotton Lane. Lower part of Thanet Beds, a few feet above Chalk	10·27	12·12	72·10
Darenth Woods. Fox and Hounds Lane. Lower Thanet Beds, just above Chalk	20·02	11·20	44·25
Hulbury, Lullingstone. Lee's pit. Thanet Beds, lower part	4·50	3·52	67·25
Bean. Mounts Wood denehole. Thanet Sand, upper part	4·25	2·52	54·75
Reculver. Cliff section. Thanet Beds, upper part	2·77	17·97	43·82
Pegwell Bay. Cliff section. Yellow loam, indurated. Highest Thanet Beds seen, but still in lower part of deposit	9·85	59·00	28·35
Pegwell Bay. Cliff section. Thanet Beds, lowest part, just above Chalk	11·87	64·62	22·87

BEDS OF SOUTHERN SIDE OF LONDON BASIN.

Sand Grades.				Equivalent Grade. mm.	Grading Factor.	Remarks.
>·1 mm. <·125 mm.	>·125 mm. <·15 mm.	>·15 mm. <·2 mm.	>·2 mm.			
% wt.	% wt.	% wt.	% wt.			
19·99	35·47	12·36	3·59	·119	·744	Buff sand.
22·65	3·10	—	—	·085	·781	Fine yellowish-buff sand.
6·59	57·04	20·12	10·16	·146	·834	Pale sand.
6·01	1·32	—	—	·059	·581	Greyish-buff coarse silty loam.
13·98	58·50	11·80	6·37	·134	·835	Pale-yellow sand.
67·75		15·00	1·30	·120	·800	Pale-buff sand.
29·86	50·26	4·22	1·88	·120	·834	Pale-buff sand.
29·62	4·90	0·48	—	·087	·751	Fine, pale-coloured sand.
—	—	—	—	·059	·693	Greyish-buff coarse silt.
22·34	8·32	0·48	—	·086	·761	Fine, pale-buff sand.
11·26	1·72	—	—	·076	·758	Pale-buff coarse silt.
7·88	2·64	—	—	·062	·592	Pale-buff coarse silty loam.
37·00	39·67	3·22	—	·110	·788	Pale-buff sand.
6·70	0·82	—	—	·066	·736	Buff coarse silt.
54·40	22·87	2·34	—	·109	·829	Pale-buff sand.
8·02	1·37	—	—	·070	·748	Greyish-buff coarse silt.
39·16	4·95	—	—	·094	·838	Fine yellowish-buff sand.
30·30	4·58	—	—	·090	·823	Fine yellowish-buff sand.
51·15	11·77	0·51	—	·102	·824	Pale-buff sand.
8·40	0·84	—	—	·073	·746	Pale-coloured coarse silt.
4·80	0·71	—	—	·064	·669	Greyish-buff coarse silt.
20·85	1·65	2·03	—	·067	·469	Greyish-buff coarse silty loam.
23·10	1·63	—	—	·086	·798	Fine yellowish-buff sand.
36·50	1·98	—	—	·090	·801	Fine greyish-brown sand.
33·87	1·57	—	—	·080	·656	Very fine yellowish-buff sand.
2·80	—	—	—	·042	·558	Yellow, calcareous, medium silty [loam.
0·64	—	—	—	·037	·555	Pale yellowish-grey fine silty loam

This remarkable feature in the Thanet Beds, although apparently universal in Kent, appears to be wanting farther west, in Surrey. From an examination of samples in that area the writer noted that in the upper part of the Thanet Sand an increase in the Equivalent Grade value was accompanied by a diminution in the Grading Factor. This feature was traced as far east as Charlton, where the writer found that the extreme top of the Thanet Sand, whilst giving the highest Equivalent Grade value of any Thanet Sand analysed, gave a somewhat lower Grading Factor than was expected. It seems likely that the readjustment of conditions which resulted in the succeeding Woolwich and Reading Beds being of marine type in East Kent, and of estuarine and freshwater type farther west, commenced before the deposition of the Thanet Beds had been completed.

(*To be continued.*)

REVIEWS.

WILLIAM SMITH: HIS MAPS AND MEMOIRS. By THOMAS SHEPPARD, M.Sc., F.G.S., Curator of the Hull Museum. pp. 75–253 (the original pagination is retained), with 48 plates and other illustrations. Hull: A. Brown & Sons. 1920.

IN these days of specialization the study of the history of the rise and progress of our science receives less attention than in earlier times. In the writer's youth, for instance, a historical question on each of the subjects for the Natural Sciences Tripos at Cambridge was compulsory, but this has long ceased to be the case. This is a pity, for apart from sentimental considerations, the student will reap much advantage from a study of the difficulties with which his predecessors were confronted, and of the mistakes which they made. One of the troubles of a geologist who has to work in a country of which the geology is unknown is due to the fact that his field-work at home is learnt in an area which has been mapped in detail. By studying the life and work of Smith, he will discover how the work was done in England at a time when its geology was practically unknown.

The importance of William Smith's work is now universally recognized, but it was not always so. In Dr. Brewster's *Edinburgh Journal of Science* for April, 1831, unjust censure was passed upon the Geological Society of London for awarding the first Wollaston Medal to Smith. The action of the Society, however, was fully justified by a writer "F." in the first number of the *Monthly American Journal of Geology*, published in July, 1831, who passes high encomium upon Smith's work.

But although the importance of the work is so generally recognized, we have up to now not been in possession of a very full and detailed account of it. Professor J. Phillips's *Memoirs of William Smith, LL.D.*, appeared in 1844, but the book is now very scarce. In 1897 the late Professor Judd contributed an important paper to the GEOLOGICAL MAGAZINE on "William Smith's Manuscript Maps". Much scattered information about Smith is incorporated in Mr. Sheppard's work, and noted in the bibliography at the end of the book. But a detailed account of the labours of the "Father of English Geology" did not exist. Now, thanks to Mr. Sheppard, and to the wise policy of the Yorkshire Geological Society, from whose Proceedings the memoir is reprinted, we have it.

It is indeed fortunate that Mr. Sheppard undertook the task of writing the work. A skilled geologist, he is also fully versed in the scientific methods of the historian and bibliographer, and has evidently left no stone unturned in his efforts to trace Smith's various publications and manuscript writings, with the result that we have a worthy and almost exhaustive record of Smith's contributions to science.

After a few introductory pages the author gives some notes on work connected with geological mapping and determination of the sequence of strata prior to Smith's time. Special notice is taken of the establishment of a sequence of strata from the Chalk to the Coal-measures by the Rev. John Michell, whose claims as a geological investigator have recently been presented by Sir Archibald Geikie in a *Memoir of John Michell* published by the Cambridge University Press in 1918. Stress is also laid upon the importance of the series of County Surveys published by the Board of Agriculture in 1794 and the succeeding years, many of which indicate by colour the nature of the soils. As Mr. Sheppard remarks, "there is no doubt they were of guidance to Smith in his work."

The greater part of the book (pp. 103–80) is occupied with an account of Smith's various publications—maps, sections, books, and papers, in chronological order. This is of the highest value, and evidently entailed an enormous amount of research. It is admirably illustrated by reproductions of maps, sections, title-pages of books, tables of strata, and other material.

The fullest details are naturally reserved for those works and portions of works which deal with Yorkshire, but anyone who wishes to obtain an account of Smith's work will do so. Many of the items refer to previously unknown or forgotten publications brought to light by the author after exhaustive inquiries. The concluding parts of the book treat of Smith's MSS., notices of his work by other writers, apart from those which have been previously published, memorials to Smith, with illustrations of busts, portraits, dwelling-places, and monuments, also some appendices and a bibliography.

A few trifling misprints occur, but there is a discrepancy between the description of the plate facing p. 107, "The original Table of Strata near Bath, dictated by W. Smith, and written by the Rev. Joseph Townsend, in 1799," and the inscription on the table by Smith on p. 108, "This Table of Strata, dictated by myself, is in the handwriting of the Rev. Ben^{n}. Richardson, and was first reduced to writing at the house of the Rev. Joseph Townsend, Pulteney St., Bath, 1799. William Smith." On p. 134 the author, referring to a copy of *Strata identified by Organized Fossils*, states that in the copy in the possession of the Geological Society of London the covers are fortunately preserved, but that the date of part iii is torn off. The writer of this notice has a copy with the covers intact, and the date of part iii is, as given by the author, "September 1, 1817."

Mr. Sheppard must be heartily congratulated upon the appearance of this most important work, and thanks tendered to the Fellows of the Yorkshire Geological Society. Every geologist should read the book, and no student of the history of geological discovery, or collection of works bearing thereon, can afford to be without it. We learn from the preface to Mr. Sheppard's work that more

information concerning William Smith's geological labours may be expected of him, for he states that " I have examined the collection of maps in the London Geological Society's library, which I am cataloguing at the Society's request ". Perusal of the present work will make all its readers anxious for the appearance of another.

J. E. M.

THE CORRELATION OF THE QUATERNARY DEPOSITS OF THE BRITISH ISLES WITH THOSE OF THE CONTINENT OF EUROPE. By CHARLES E. P. BROOKS, M.Sc., F.G.S. Smithsonian Report for 1917. pp. 277–375.

A PAPER of considerable importance to students of Pleistocene geology. It contains a summary of the chief writings upon the Pleistocene beds of various European countries, and an account of the British deposits. This summary will be found to be very useful to workers among these little-understood accumulations, and will save much reading of literature of various foreign countries. The author naturally attempts correlation of the British deposits with those of other countries. " In general the relations of the stages appear to be as follows :—

Cold period	. .	Pre-Chellean.
Warm period	. .	Chellean. Chelleo-Acheulian.
Cold period	. .	Acheulian-Mousterian.
Warm period	. .	Mousterian.
Cold period	. .	Aurignacian. Solutrean. Magdalenian."

It will be seen that this classification differs in many respects from those of other writers. One feels that the time has not yet arrived for correlations over wide areas. Much more evidence must yet be obtained, but the author's paper will afford help to those occupied in obtaining that evidence.

J. E. M.

THE GEOLOGY OF THE COUNTRY AROUND LICHFIELD, INCLUDING THE NORTHERN PARTS OF THE SOUTH STAFFORDSHIRE AND WARWICKSHIRE COALFIELDS. By G. BARROW, W. GIBSON, D.Sc., T. C. CANTRILL, B.Sc., E. E. L. DIXON, B.Sc., and C. H. CUNNINGTON, B.Sc.; with contributions by J. B. HILL, R.N., T. EASTWOOD, A.R.C.Sc., and J. PRINGLE. Memoirs of the Geological Survey of England and Wales. Explanation of Sheet 154. pp. vii + 302, with one plate. 1919. 9*s*. net.

THE area covered by the map which this memoir describes includes a considerable part of the North Warwickshire Coalfield, and also that part of the South Staffordshire Coalfield which lies to the north of the Bentley faults. All the old work connected with the

pre-Carboniferous rocks and the productive Coal-measures is revised and brought up to date with modern mining information; interesting accounts are given of the structural features, particularly of the boundary faults, and the modern subdivisions of the red rocks of the Upper Coal-measures are described in very considerable detail. With regard to the productive Coal-measures, an interesting fact is that in the North Warwickshire field the lower coals have been found to improve towards the north, and that there is now talk of reopening old pits which were originally only sunk to the seven-feet coal higher in the series and sinking them to these lower coals. With regard to the Upper Coal-measures, a satisfactory subdivision comparable with that well known in North Staffordshire has now been established for this area. The Black-band Ironstone Group is absent, but the Etruria Marls, with their characteristic Espley rocks, are of normal type. The succeeding Halesowen Sandstone comprises two subdivisions, a lower series of sandstones and an upper one of marls with *Spirorbis* limestones; one of these, the "Index Limestone", at the base of the marls, and resting on a well-marked sandstone, is of great value in mapping and determining the depths of the coals. The Keele Beds are the normal red marls with *Spirorbis* limestones, but are overlaid by 2,000 feet of red sandstones, the Hamstead Beds, which seem to be definitely pre-Permian, and are therefore included in the Coal-measures. The accurate recognition of horizons in these rocks is a question of great importance, since the possibility or otherwise of the presence of coal at workable depths may depend entirely on the correctness of the diagnosis. As an instance of this, the country between Tamworth and the Western Boundary Fault of the North Warwickshire Coalfield may be quoted. Here rocks which were originally mapped out as Keuper Sandstone have now been proved, by the recognition of *Spirorbis* limestones associated with the peculiar rock-type known as Pellet Sandstone, to belong to the Keele series. This determination allows a fairly definite idea to be formed about the depth of the coal, whereas, on the former mapping, no estimate could have been given owing to the great unconformity existing between the Coal-measures and the Trias.

Both the coalfields described are bounded on both sides by faults of considerable downthrow. These faults show many points of interest, and not the least of these is the great width of the disturbed areas, which has been proved by the driving of exploratory headings. One of these headings, driven through the Eastern Boundary Fault of the South Staffordshire Coalfield, from the Walsall Wood Colliery's workings, proved the disturbed area to be 350 yards wide, while further south at Aldridge the belt of disturbance is 1,200 yards wide. In the first of these explorations the heading left the Shallow Coal and was driven for 75 yards through measures with broken masses of coal, for the next 73 yards it passed through grey measures much squeezed and compressed, dipping 24 degrees E.N.E.; from a distance of 148 yards to 350 yards from the starting-point the rock

was all red and mottled marls, faulted and broken for the first 100 yards, and over the second 100 yards dipping more regularly at about 26 degrees. At 350 yards the heading passed through another fault, and beyond this into red marl correlated with the Keele Beds and having a still gentler dip of 16 degrees.

This and the evidence from the other boundary faults shows that they, like many other important lines of dislocation, are areas of wide shattering and step faulting, partaking more of the nature of broken folds than of clean fractures, a phenomenon which is well seen in some other coalfields.

Another point of interest about these faults is their throw in post-Triassic time, which is large in comparison with that observed elsewhere. This post-Triassic throw commonly amounts to 200 to 400 feet, while in two cases it exceeds 700 feet. The possibility of the existence of workable coal between the two coalfields is reviewed, but here the grounds on which the estimates can be made are far from secure. The unconformable relations between the Trias and the Coal-measures, the difficulty of determining the post-Triassic throw of faults, and in the southern portion the possibility of uprising of the pre-Carboniferous floor, all tend to render the formation of definite opinions a very difficult task. The one fact which stands out appears to be that the coal over a large part of this concealed coalfield must be deep, in places as much as 3,900 feet. The most promising areas appear to be in the northern part, where the Keele Beds are absent, though here sinkings would have to pass through the heavily watered Bunter. The surface of the area is in many places thickly covered with drift which must have rendered surface mapping very difficult, since in many places temporary exposures laid bare in digging for sewers and foundations are all which can be obtained. The officers of the Geological Survey have, however, been very fortunate in the co-operation of the colliery managers, and the structure of the coalfields seems now to be established on a very satisfactory basis. The map accompanying the memoir is not yet published owing to causes connected with the War.

W. H. W.

A Contribution to the Knowledge of the Mesozoic Igneous Rocks developed around the Tsushima Basin, Japan. By Takeo Kato. Journ. Geol. Soc. Tokio, vol. xxvii, Nos. 316 and 317, 1920.

In these two papers a description is given of a series of igneous rocks of late Mesozoic, probably Cretaceous, age, occurring in the neighbourhood of the Straits of Tsushima. The series comprises an extrusive phase of andesites and rhyolites, more or less metamorphosed pneumatolytically by a granitic intrusion allied to the masanite of Professor Koto, the whole being subsequently penetrated by a series of acid dykes similar to the granite. It therefore affords an example of a complete normal sequence of eruptivity of Pacific

type, comprising volcanic, plutonic, and hypabyssal phases; obviously derived from a common magmatic basin. The intrusives also give evidence of a certain amount of magmatic differentiation in the form of leucocratic and melanocratic facies, with aplites and pegmatites.

THE NOMENCLATURE OF PETROLOGY. By ARTHUR HOLMES, D.Sc., A.R.C.S., F.G.S. pp. 284. London: T. Murby & Co. 1920. Price 12*s.* 6*d.* net.

SOME years ago the author began to compile a card-catalogue of petrographic terms for the use of students at the Imperial College of Science; in view of the usefulness of this catalogue and in response to many suggestions he has now developed and published it in a handy form.

In the Introduction of twenty-one pages the subject of petrographic nomenclature is discussed in general terms, and with the author's remarks as to its complexity and the unnecessariness of many of the names employed by various authors we are in hearty agreement. Some petrologists really seem to have gone out of their way to coin cumbersome and jaw-breaking names, almost impossible to remember or to spell, and conveying nothing as to the actual character of the rock. In view of the Committee on Petrographic Nomenclature now sitting it would be unseemly to enter into a general discussion of the principles to be adopted in the future, but the author's temperate statement of his views may be read with profit by all petrologists.

The greater part of the book naturally consists of a glossary or dictionary of petrographic terms, including structures and properties as well as types, and including those referring to igneous, sedimentary, and metamorphic rocks. Under each heading a brief definition is given, with in many cases the name of the introducer of the word and one or more references to the literature. The list appears to be comprehensive and well selected; a few more explanations might well have been given of terms employed in economic geology, as by miners, and in the records of bores. Thus we find that most of the Scottish terms are included, while their English equivalents appear to be omitted. We confess that it is very difficult to give any precise definition of many of these words, owing to the vagueness of their use; they are, however, very puzzling to students and might well have been included with some sort of explanation, even if only a statement that they cannot be defined precisely. In this connexion we are pleased to note that the author invites suggestions from petrologists as to terms to be included in another edition.

Some useful appendices are added to the text, giving glossaries of the more common and important French and German petrological terms, lists of Latin and Greek words and prefixes, and tables of classification, the latter being largely based on the so-called degree of saturation of the rock, as suggested by Shand. Although we have

noted a few trifling misprints, especially in the tables, the book seems to be remarkably free from errors, and gives evidence of a great amount of careful work and investigation of the complicated and scattered literature on the subject.

Hæmatite and Rutile formed by the Action of Chlorine at High Temperatures. By H. E. Merwin and J. C. Hostetter. The American Mineralogist, vol. iv, No. 10, October, 1919, pp. 126 and 127.

IRON and titanium compounds were removed from the walls of a glass-pot by the action of chlorine at temperatures between 1000° and 1100° C., and deposits of hæmatite and rutile crystals of comparatively large size were formed. The hæmatite crystals were 4 mm. in diameter and the rutile crystals about 1 mm. long. The angles between the faces were measured and found to agree with those of the natural minerals. Hæmatite was shown to contain a very small proportion of FeO in solid solution, and it is suggested that this method might be used to prepare crystals with varying amounts of FeO in order to study possible variations in the angles.

W. H. W.

The Economic Geology of the Central Coalfield of Scotland, Area VII (Rutherglen, Hamilton, and Wishaw). Mem. Geol. Survey, Scotland. pp. vii + 140, with 6 plates and 4 figures. 1920. Price 7*s.* 6*d.* net.

SEVERAL of the memoirs of this series have already been noticed in the Magazine, and this volume follows closely on the lines of its predecessors. It deals with some of the most important mining ground in the county of Lanark with a small area in Renfrew, extending from Rutherglen to Newmains, including Cambuslang, Uddingston and Bothwell, Hamilton, Motherwell, and Wishaw. The district on the whole forms part of a deep basin, running from north-west to south-east, with its centre near Uddingston, and limited on the south-west by the Dechmont fault, with a throw of about 3,600 feet. Owing to the depth of the coals in the centre of the basin, they formed a reserve for some time, while neighbouring districts were approaching exhaustion, but even this has now been extensively worked, and it is improbable that the output will increase very much, though it may be maintained for a good many years. In 1913 the county of Lanark yielded 41 per cent of the total Scottish coal-production.

The district is almost entirely composed of Coal-measures, with a small strip of Millstone Grit in the north-east, and Lower Carboniferous rocks only to the south-west of the great Dechmont fault. There are also various superficial deposits, including pre-Glacial sands and gravels, boulder-clay, and various sands,

gravels, and clays overlying it, and certain deposits of the 100 foot terrace, with peat and other recent formations. Some of these are of economic value for brick-clays, moulding and furnace sands, and other purposes.

THE GEOLOGY OF THE MID-CONTINENTAL OILFIELDS. By T. O. BOSWORTH, D.Sc., M.A., F.G.S., F.R.G.S. pp. xii + 314. New York: The Macmillan Company. 1920.

DR. BOSWORTH has provided in this volume a most useful addition to oil-field literature. It is in the main an epitome of the voluminous and detailed work which has been carried out in this area by the United States Geological Survey and other workers. It is no light task, even if one has access to the numerous American publications, to abstract from them the specific information required, and it is this task which the author has taken in hand, and he has shown a wise discrimination in selecting from the vast amount of detail available the salient points to form a general, yet in certain respects detailed, summary of the whole.

The material is on the whole well arranged, though perhaps it might be said to suffer from over-classification. The book is divided into "parts", "chapters", and "sections", and especially in the later portion of the book there is a quite needless multiplicity of chapters, while the headlines throughout are rather reminiscent of the American press.

The work is supplemented by a very full bibliography (chap. ii), and numerous references throughout the text. Part iii gives an account of the vigorous development of the field which brought it from its modest production prior to 1903 to its present position of producing nearly one-third of the world's annual oil output, and is of especial interest at the present time when so much is being written on the world's supply of oil and America's present and future position.

The text throughout is well supplemented with plans, geological sections, tables, etc., together with a number of photographs. The author first discusses the general structure and stratigraphy of the region, and then gives in parts vi and vii a more detailed account of the local characteristics of the different fields. Parts ix and x give an account of natural gas and its relation to the distribution of oil, together with an outline of the methods employed for the recovery of "gas gasoline", a process rapidly increasing in economic importance with the ever-increasing demand for light spirit. The subject of helium is dealt with, a matter of which, owing to the activities of the censor, we heard little at the time of its discovery in commercial quantities in 1917, but one which, had the supplies of gas been mid-European instead of mid-Continental, would more than probably have been brought forcibly to our notice.

In part xii the author finishes with some "general conclusions", but we rather disagree with him that "some conclusions seem inevitable". The volume is so essentially a collection and statement of facts that part xii might well have been omitted without much loss, especially as those who will use the book presumably have, or should have, at least a general knowledge of the theories of the origin and concentration of oil and gas. That subject in itself is so extensive and important that to skim lightly over it in a page or two hardly strikes one as in keeping with the rest of the volume. As is essential to a book of this nature it is well indexed, which adds materially to its value as a work of reference.

The publishers are to be congratulated on the printing and general style of the book, though here and there exception might be taken to the proof-reading, which has been by no means perfect.

CORRESPONDENCE.

S. B. J. SKERTCHLY'S STONE IMPLEMENTS.

SIR,—I am anxious to trace the implements obtained by the late Mr. S. B. J. Skertchly from deposits of the districts around Brandon and Mildenhall, which he claimed to be of mid-Glacial age.

I should be glad if anyone in possession of any of these would kindly inform me of the fact, giving all details concerning the labels, and if possible, outline-figures of the specimens.

I trust that you will be able to help me by inserting this letter in the GEOLOGICAL MAGAZINE.

JOHN E. MARR.

SEDGWICK MUSEUM, CAMBRIDGE.
August 5, 1920.

LINGULA IN THE CHALK.

SIR,—Mr. G. W. Butler will find published records, now of some standing, in Brydone's *Stratigraphy and Fauna of the Trimmingham Chalk* (London: Dulau & Co., 1900), and in Griffith & Brydone's *Zones of the Chalk in Hants.* (London: Dulau & Co., 1911). At Trimingham it has been found both in the white chalk and in the grey chalk.

R. M. BRYDONE.

27 MAYBURY MANSIONS,
MARYLEBONE STREET, W. 1.
July 24, 1920.

PHYSIOGRAPHIC RELATIONS OF LATERITE.

SIR,—At the end of his article in the May number of the Magazine Mr. F. Dixey gave a summary of the conditions affecting lateritization in Sierra Leone, but did not include a physiographic factor

which appears to be of prime importance, namely, a late stage in a cycle of subaerial erosion, when the slow removal of rock waste from a worn-down land surface permits deep penetration of weathering with very slow movement of ground-water, and thus allows time for the various chemical reactions upon which lateritization so largely depends. The general statement of this aspect of the problem is as follows.

Conceive the changes suffered by a recently elevated region, composed mostly of such rocks as commonly underlie laterite. In the early or youthful stages of the cycle of erosion thus introduced, narrow valleys will be incised by the main rivers; the steep valley sides will exhibit bare rock or will be thinly covered with coarse rock waste which creeps rapidly down the slope to the river below, while the ground-water percolates downward more rapidly still. Laterite cannot be formed under such conditions. In a later or mature stage of the cycle, many branch valleys will also be incised, and all the valleys will be opened to slopes of a moderate degree; both strength and variety of relief will thus reach their greatest values. The valley sides will then be covered with a thicker cloak of finer rock waste, but the down-slope creep of the waste and the downward percolation of the ground-water will still be comparatively rapid; little or no laterite will be formed. In still later and much longer-enduring stages of the cycle, the valleys having been already deepened about as much as possible, the inter-valley hills will be slowly subdued to moderate or small relief, and their slopes will be reduced to gentler and gentler declivity. Thus a condition is reached in which the removal of rock waste from the general surface of the region and the movement of ground-water are very much slower than they were on the side slopes of the mature valleys. Weathering will now enter to greater and greater depths, ground-water will linger in the deep soil, and chemical changes will have time for deliberate operation. If no upheaval of the region takes place, the subdued hills may eventually be worn down to the gentle undulations of a peneplain, in the old age of the cycle, and on such a surface the processes of lateritization find their optimum.

If upheaval takes place after the peneplanation and lateritization of a region, the laterite will be quickly removed where narrow valleys are rapidly incised in the early stages of the new cycle of erosion; but the laterite will remain on the upland areas until, as maturity is approached and reached, these areas are invaded and consumed by branch valleys. The occurrence of laterite in different parts of the world gives much support to this view of its origin.

The relation of lateritization to physiographic old age thus involved is indirectly implied in Mr. Dixey's statement that "in the more hilly and mountainous parts of [Sierra Leone] . . . laterite is not nearly so well developed" (p. 214). It would be interesting to learn if the other areas, where "the solid rocks have been lateritized to

a considerable depth", show worn-down surfaces of low relief. Holmes is quoted as saying that "the steep slopes of the Inselberg[1] peaks and mountain blocks [of Mozambique] are always free from deposits of lateritic constituents"; but the stage of physiographic evolution in areas where laterite occurs is not mentioned. In Fermor's review of the studies by Lacroix on laterites in Guinea, to which reference is made by Mr. Dixey in a footnote, it is said that "lateritization is everywhere intense where the slope of the ground is low enough to permit the infiltration of water and allow it to remain for a long time in contact with the rocks" (GEOL. MAG., 1915, p. 128). As laterite is usually developed on deformed or crystalline rocks, the most probable means of giving them a surface of low slope is by long-continued degradation; that is, by permitting their physiographic evolution to advance to a late stage in a cycle of subaerial erosion.

The principle here involved has found application in the active search for manganese ores by members of the U.S. Geological Survey during the War; for the ore was often found to be related to some former lowland of erosion, now uplifted and more or less dissected. The nickel ore of New Caledonia is similarly situated; it occurs on uplands which, as far as I could judge, during a trip around that long island in 1914, are residuals of an uplifted and submaturely dissected peneplain (see "Metalliferous Laterite in New Caledonia": Proc. Nat. Acad. Sci., vol. iv, 1918, pp. 275–80).

W. M. DAVIS.

HARVARD UNIVERSITY.
May, 1920.

GLACIAL EROSION.

SIR,—I must leave it to my friend Professor Gregory to discuss in detail Professor W. M. Davis' paper on "The Glacial Erosion of Snowdon", but as the question covers a far wider area, I should like to state that I still think glacial erosion to have been, comparatively speaking, an agent of minor importance in the formation of mountain valleys. My views were expressed in the paper on "Alpine Valleys in relation to Glaciers" (Quart. Journ. Geol. Soc., 1902, p. 690), in which I refer to three others in the same journal in 1871, 1873, and 1874, which three were the fruit of some fifteen years' work. Since then I have visited the Alps (more than thirty three times in all), the Pyrenees, and several other regions, with this question always in mind, with the result that I doubt whether Professor Davis has really explored any of the regions which I describe. How many of the lateral valleys in the Alps has he ascended to their head? Has he seen the Creux de Champ, the Fer à Cheval, the Am Ende der Welt, the Croda Malcora,

[1] Is the English language really so geographically incompetent that we must say Inselberg, Hinterland, and Thalweg instead of residual mountain, back country, and stream line?